Aalto University
School of Engineering

Department of Engineering Design and Production

Wycliffe Raduma

Search for Best Practice in Education: Machine Design in Aalto University

Thesis submitted in partial fulfilment of the requirements for the degree of Master of Science in Technology

Espoo, September 05, 2012

Supervisor Professor Kalevi Ekman
Advisor Juha Forsblom MSc (Tech.), MA

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I am grateful, to the teaching staff and fellow students that I have worked with, for the world-class education that I have received. This work is my contribution to an already excellent educational programme. There is always room for improvement.

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During my years of studying mechanical engineering at TKK and Aalto University, I have taken every opportunity I have had to choose an educational path that highlights my passions and strengths. My childhood aspirations to become a pilot or a scientist lead me to pursue a degree in Aeronautical Engineering after high school. This brought me to studying Mechanical Engineering at TKK. When the time came to choose my major, I was fascinated by programming, and electronics. This led me to major in Machine Design, specifically Mechatronics, rather than Aeronautical Engineering. When looking for a suitable minor, I studied programme guides carefully and learned of exciting opportunities to partake in project-based studies from TKK, TaiK, and HSE. My new-found interest in an interdisciplinary degree led me to change my major to Product Development and to pursue a minor in International Design Business Management (IDBM). I am extremely pleased with the entire experience and the opportunities it has brought.

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Wycliffe Raduma

Aalto University
School of Engineering

Aalto University, P.O. BOX 11000, 00076 AALTO
www.aalto.fi

Abstract of master's thesis

Author Wycliffe Raduma		
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Abstract

What are best practices and how are they relevant to Aalto University's Department of Engineering Design and Production (KoRa)? This study looks into best practices in engineering education through the CDIO Initiative's standards, syllabus, and philosophy to find out how suitable the CDIO standards are for KoRa. In the process, stakeholders are involved by using participatory action research (PAR) methods in the form of a workshop. A Teaching Evaluation Exercise (TEE), which is running parallel with this study, is observed closely in order to diagnose the state of education at KoRa. The results of the TEE self-evaluation are used to evaluate KoRa according to the CDIO standards. The results of the TEE panel's report are used to study best practice closely and develop tools for introducing best practices at KoRa.

How can best practices be adopted at KoRa? There are three sets of tools that are developed: physical tools, intellectual tools, and virtual tools. Physical tools are spaces, such as a Math & Physics Gym, which enhance the learning experience by developing the working environment. Intellectual tools are ways of working that change the organisation. Three intellectual tools are introduced: the Ice Breaker Programme, which is a tool for maximising students and alumni as resources for education and research, the Black Box Workshop (Inspired by Edström's Black Box Exercise), which is a tool for integrated curriculum design, and the Inverted Classroom, which is a way of transforming teaching into coaching. The virtual tool introduces is Aalto Cloud, which is an all-inclusive web service for managing courses and supporting lifelong learning.

The study concludes by revising the strategic implications of this study's results, giving a few suggestions for future research, and a call to action to decide on joining CDIO officially or unofficially. The main benefit of CDIO would be the network of universities – resulting in increased international collaboration. The danger is if CDIO is adopted with the wrong attitude; the attitude that the standards are definitive. CDIO standards are recommendations – not standards.

For KoRa to work towards Aalto University's ambitious strategy, it is essential that that universities collaborate, adopt a learner-centred attitude, take command of modern teaching and learning tools, and use students and alumni are resources in teaching and research. The suggested tools are ways of enforcing these four essential goals.

Keywords CDIO, Inverted Classroom, Engineering Education, Education Reform, E-learning, Blended Learning, Student Assessment, Aalto University, Mechanical Engineering, Department of Engineering Design and Production, KoRa

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Commonly Used Terms and Abbreviations

Aalto	Aalto University
Aalto ENG	Aalto University School of Engineering
Aalto SCI	Aalto University School of Science
Aalto ELEC	Aalto University School of Electrical Engineering
Aalto CHEM	Aalto University School of Chemical Technology
Aalto ARTS	Aalto University School of Art and Design (also Aalto TAIK)
Aalto ECON	Aalto University School of Economics
Alignment of ILOs	Aligned ILOs (intended learning outcomes) are learning outcomes that are supported by teaching and assessment practices, and contribute to the overall intended learning outcomes of courses, modules, and programmes
AST	Aalto University Schools of Science and Technology; Former TKK, Currently divided into Aalto ENG, SCI, ELEC, and CHEM
Best Practice	A practice in education that promotes learning-centred education where learning is based on constructivism, learners and teachers produce new knowledge, and learners understand how to apply their knowledge for the benefit of society. Even though best practices commonly work well, their weakness is that they grow old. Therefore, they need to constant re-evaluation.
Blended Learning	A mix between e-learning and contact teaching. Contact teaching is lecturing, guided classroom teaching and such

CDIO	An educational approach aimed at graduating engineers who can: *Conceive-Design-Implement-Operate complex value-added engineering products, processes and systems in a modern team based environment* (Crawley, et al., 2007)
Constructivism	A school of thought in teaching that argues that new knowledge builds on old knowledge
Crowdsourcing	Using the small efforts of the individuals that form a crowd in order to complete a task that requires a large effort.
Didactic Teaching	Teacher-centric and instructive teaching, where student interaction is not necessary, e.g. a lecture. The contrasts are participative teaching and PBL, which are student-centric approaches.
E-learning	The use of technology in learning opportunities, namely ICT (Information and Communication Technology)
ICT	Information and Communication Technology
ILO	Intended learning outcome
Interim Analysis	A method of analysis, where data collection, sorting, and analysis is done, more or less, in parallel
KoRa	Department of Engineering Design and Production
PAR	Participatory Action Research (a variant of action research)
PBL	Problem-based learning. Synonymous to enquiry-based learning (EBL)
TEE	Teaching Evaluation Exercise; an internationally standardised internal audit carried out by universities in order to evaluate

	their education programmes. TEE has two phases that yield separate documents: self-evaluation, and an external panel's evaluation
TKK	Helsinki University of Technology. Known as Aalto School of Science and Technology since 1st January 2010; divided into Aalto ENG, Aalto SCI, Aalto ELEC, and Aalto CHEM since 2011
SOLO Taxonomy	Structure of the Observed Learning Outcome (SOLO) taxonomy. A tool for defining intended learning outcomes (ILOs) and learning assessment. A model for describing levels of increasing complexity in learning. Similar to Blooms taxonomy
Skills, Human	A term to collectively describe professional, personal and interpersonal skills
Skills, Professional	A term to collectively describe product, process and system building skills
Skills, Technical	Technical and scientific knowledge and understanding that is specific for an engineering degree programme; disciplinary knowledge and understanding
Skills, Engineering	A combination of human skills, technical skills, professional skills, and the associated practical skills
STOPS	Software for Target-Oriented Personal Syllabus. A pilot of an opened computer-aided multipurpose tool that is to be used as a syllabus and as a tool for developing course content

1 Introduction

"The illiterate of the 21st century will not be those who cannot read and write, but those who cannot learn, unlearn, and relearn"

- Alvin Toffler

The real-world demands, i.e. the context of engineering education, have been scrambling forward with the development of technology and shifting focus according to the changing environment (Crawley, et al., 2007). In contrast, teaching in the undergraduate and graduate engineering education has been developing incrementally – without enough emphasis on the multidisciplinary nature of technology, the endangered environment, the importance of international markets, and the development of information and communication technology, among other changes (Rugarcia, et al., 2000).

The aim of this study is to find adoptable **best practices**[1] in mechanical engineering education, and to suggest how to introduce these best practices into **KoRa**'s[2] curriculum by making use of **CDIO**[3], research findings, and the current state of radical change within **Aalto**[4].

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[1] Best practice (in education) refers to teaching practices that have been deemed excellent or practise that improve teaching and learning.

[2] KoRa is the Department of Engineering Design and Production. It is a part of Aalto University's School of Engineering

[3] *"The CDIO™ INITIATIVE is an innovative educational framework for producing the next generation of engineers. The framework provides students with an education stressing engineering fundamentals set in the context of Conceiving — Designing — Implementing — Operating real-world systems and products. Throughout the world, CDIO Initiative collaborators have adopted CDIO as the framework of their curricular planning and outcome-based assessment."* Source: http://www.cdio.org/

[4] Aalto University

Engineers should be able to conceive, design, implement, and operate complex value-adding systems as illustrated in Figure 1. Furthermore, engineers should be able to do so in a modern team-based environment. (Crawley, et al., 2007)

To elaborate on that, engineers should be able to conceptualise complex systems that add value, turn their ideas into communicable designs, produce prototypes and functional models, and end up with an operable creation, a creation that actually works and has a manageable and sustainable life-cycle. Engineers should be able to engineer when they graduate. Adopting this as the context of engineering education is the first step towards conforming to the CDIO Initiative. (Crawley, et al., 2007)

Figure 1 CDIO Illustrated

In this work, there is a lot of reference to the skills needed for engineering. Figure 2 is a map of commonly used terms to describe different sets of skills. Engineering skills refers to all the skills that an engineering student should obtain from engineering education. Technical skills and disciplinary knowledge refer to the technical and scientific knowledge and understanding that is specific for an engineering degree programme. Professional skills are skills needed to operate in a professional context logically and without unnecessary conflict. Human skills are skills needed to operate in a social, human-centred context. Practical skills refer to associated practical skills.

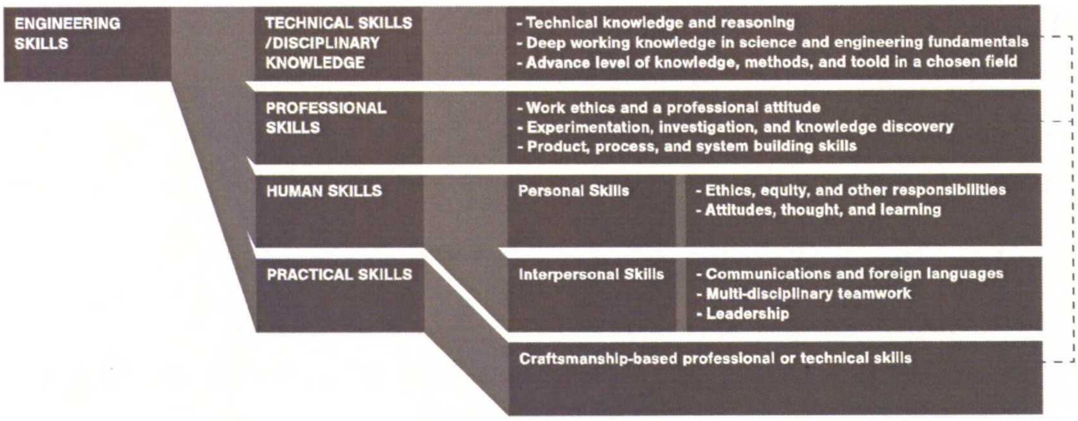

Figure 2 Commonly used terms for describing skills

1.1 Background

Essentially, the rationale behind this work is the evident need for interdisciplinary and problem-based engineering education – a rational that is in line with the CDIO Initiative. The underlining assumption in this work is that there is a need for more problem-based learning (PBL) and system engineering in interdisciplinary teams.

The need for educational reform dates back to the end of the Second World War. Since then, the knowledge provided by engineering education has been drifting further away from the real-world demands. In attempt to redefine the context of engineering education, the CDIO Initiative was started at the Massachusetts Institute of Technology (MIT). (Crawley, et al., 2007)

The drift from real-world problems is a common problem in engineering departments of universities around the world, including Aalto University's department of Engineering Design and Production (hereafter KoRa), which is the focal point of this study. On one hand, KoRa is exceptional in meeting some real-world demands, such as the need to collaborate with the industry, on the other hand, areas such as integrated learning of technical, professional, and human skills are not at the desired quality level (Aaltonen, et al., 2011). Consequently, certain practices in KoRa's engineering education have grown old in respect to the changing environment creating a need to update and consolidate teaching practices within the department.

In order to rethink the engineering education, it is necessary to understand the past and present state of engineering education, as well as have an understanding of what the future holds. Also, it is important to involve all of the four key stakeholder groups: the students, industry, university faculty, and society at large (Crawley, et al., 2007).

The CDIO Initiative is used in this work for two reasons: it deals with the issue of outdated engineering education, and it provides guidelines for reforming engineering education without a significant increase in resources. Engineering education needs to be reformed in order for the future engineers to be capable of dealing with the upcoming problems and challenges, many of which are wicked and unknown (Crawley, et al., 2007).

Engineering in the 20th century was strongly based on physics and electronics. While the world was industrialising during the 20th century and investments in research increased, engineering education had been shifting from a practice-based focus to a science-based focus referred to as engineering science. As engineering has been becoming more of a science that focuses on disciplinary knowledge, engineering educators have forgotten the value of human skills and professional skills.

Figure 3 depicts the previously mentioned shift from practice-based professions to scientific professions and suggests how the introduction of an international initiative, i.e. the CDIO Initiative, can be used to reform engineering education. (Crawley, et al., 2007)

To respond to development need in education, the administration of both Aalto and KoRa launched several initiatives, using the available resources, to develop engineering education in Aalto. This study is one of those initiatives and is unique in its approach to the subject of engineering education. A further cause for reassessment and development KoRa's degree programmes is the new university structure (Figure 14 on page 35).

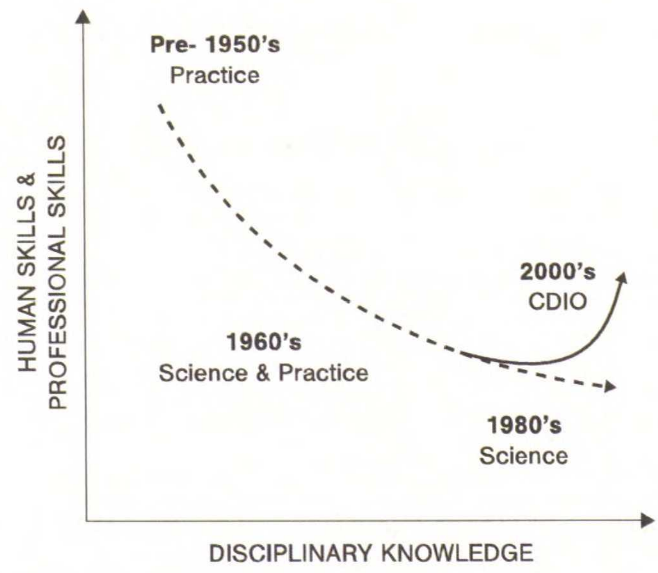

Figure 3 Evolution of Engineering Education (Crawley, et al., 2007)

The desired impact of this study is to inspire decision makers into action by:

- Share knowledge of best practices
- Providing clarity
- Presenting opportunities
- Changing attitudes

These points can be supported by discussions forums, publications that summarise relevant material about engineering education, and workshops for drawing links between disciplines. Without changes in attitude or increased resources, development will continue to be incremental (Crawley, et al., 2007).

1.2 Research Scope and Objectives

In this study the main focus is on KoRa's mechanical engineering education programmes for bachelor's and master's level studies. The scope is framed by the following research questions:

- **What are best practices and how are they relevant to KoRa?**
    - Answered in Section 3.4
- **How can best practices be adopted at KoRa?**
    - Answered in Section 6

To answer these questions, the aim can be divided into two goals that are composed of the research objectives:

1. Identify and clarify best practices in the context of KoRa
    a. Define properties of best practice in reference to CDIO
    b. Derive objectives for educational development from Aalto's strategy
    c. Diagnose the state of KoRa taking into account the historical and cultural context
2. Inspire action for sustainable educational development in KoRa
    a. Involve the key stakeholder groups: students, industry, university staff, and society
    b. Find out what is needed for sustainable change
    c. Make suggestions on how to start and sustain radical development of teaching in the degree programmes

By fulfilling these objectives, it is likely that the quality of engineering education in KoRa will meet the expectations of the stakeholders. This study can be expressed as a process (summarised in Figure 4) of collecting a relevant amount of background information that can be used to suggest and apply best practices in engineering education that are tailored for KoRa.

The main points for observation, in terms of new practices, are the CDIO Initiative, the TEE reports, observation made while working and studying at Aalto. Observations and experience from studies at Aalto Universities will give and insider's perspective the education. The TEE reports are used for both analysing teaching at KoRa, and finding best practices in education.

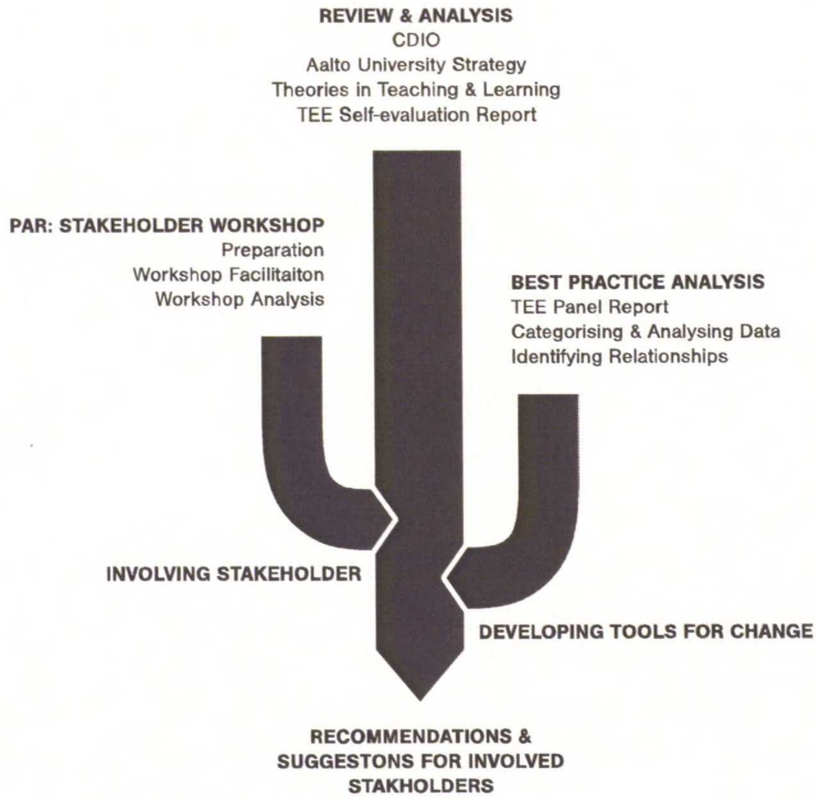

Figure 4 Objectives of the study

Because best practices come and go, this study also attempts to generate sets of tools that can be used to disseminate, enhance, or evaluate emerging best practices. Such tools are included in the suggestions and recommendations (Section 6).

Suggestions for individual courses are beyond the scope of this study; however, a few hypothetical examples are used and suggestions for improvement are made on all levels – from best practices for individual assignments to tools that can be used at a university level.

In summary:

- The rationale behind this work is the evident need for interdisciplinary and problem-based engineering education that is needed to confront the engineering problems and challenges of the future.
- The research questions to answer are:

    - What are best practices and how are they relevant to KoRa?
    - How can best practices be adopted at KoRa?
- The desired impact of this study is to inspire decision makers into action by sharing best practices, providing clarity, presenting opportunities, and changing attitudes.

1.3 Thesis Structure

Background, which is the first subsection of this introduction, introduces the problems of engineering education, which are: the general difficulties in adapting to the changing world, and the future challenges that need to be addressed. The *Research Scope and Objectives* subsection describes how the problem is approached, what the objectives are, and what problem areas will be covered.

The content beyond this section is modelled after the process of this study (Figure 4). The groundwork is done by studying relevant literature and planning the research. Research is carried out with an unconventional interim analysis process, which means that interpretation of data is mixed into the data collection process (Johnson, et al., 2004). This process is explained in Section 2.4.

The output of this study a collection of suggestions and recommendations of the action needed to improve engineering education at KoRa through tools for successful adaptation of best practices. The suggestions and recommendations, which are presented and discussed in Section 6, are based on research findings in Section 5. As a result of an interim process, data collection is followed by a compilation of research findings, which are deduced from the data and interim analysis, in Section 4. The research is supported by the theory recited in Section 3, and conducted using the methods defined in Section 2.

This thesis has a structure where the literature review and the research methods form the foundation, research findings are categorised and clarified in the form of data collection and analysis, and suggestions and recommendations conclude the study

(Figure 5). The suggestions and recommendations are the most important part of the study.

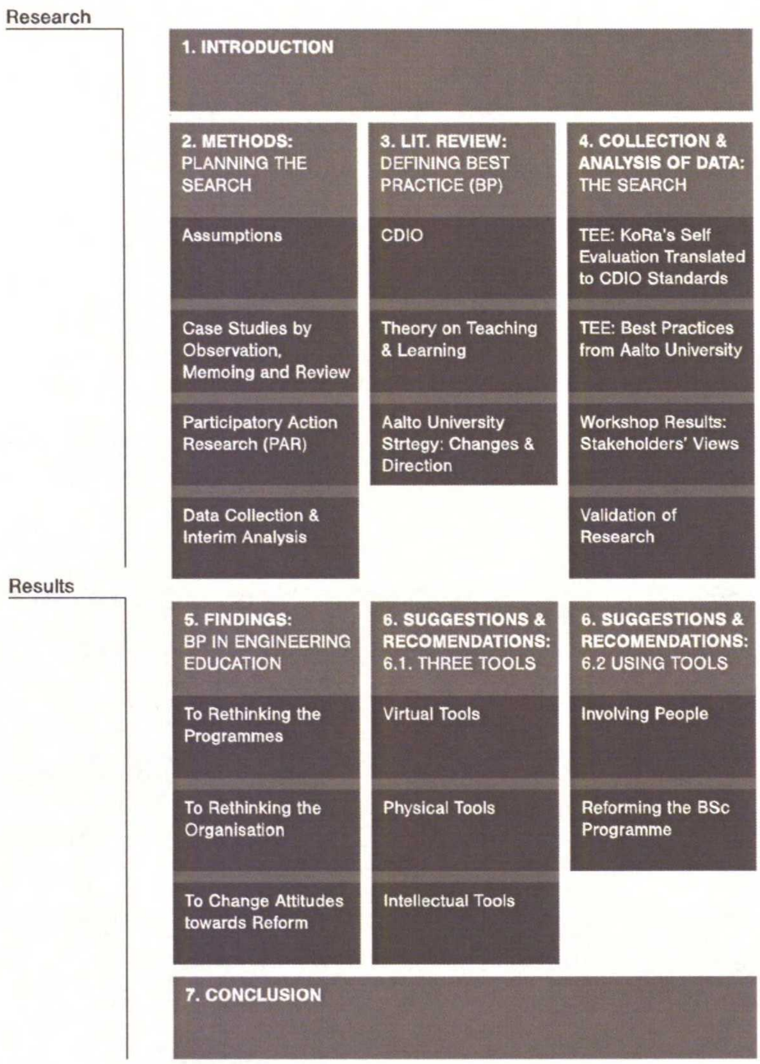

Figure 5 Thesis Structure as built from the top down

2 Methods: Planning the Search

In general, the methods used to gather information are:

- Inductive literature review (Johnson, et al., 2004)
- Case study (Denzin, et al., 2005)
    - A detailed literature review
    - Observation
    - Memoing
- Participatory action research (Denzin, et al., 2005): workshop

Figure 6 is an overview of methods used to construct the research process behind this study.

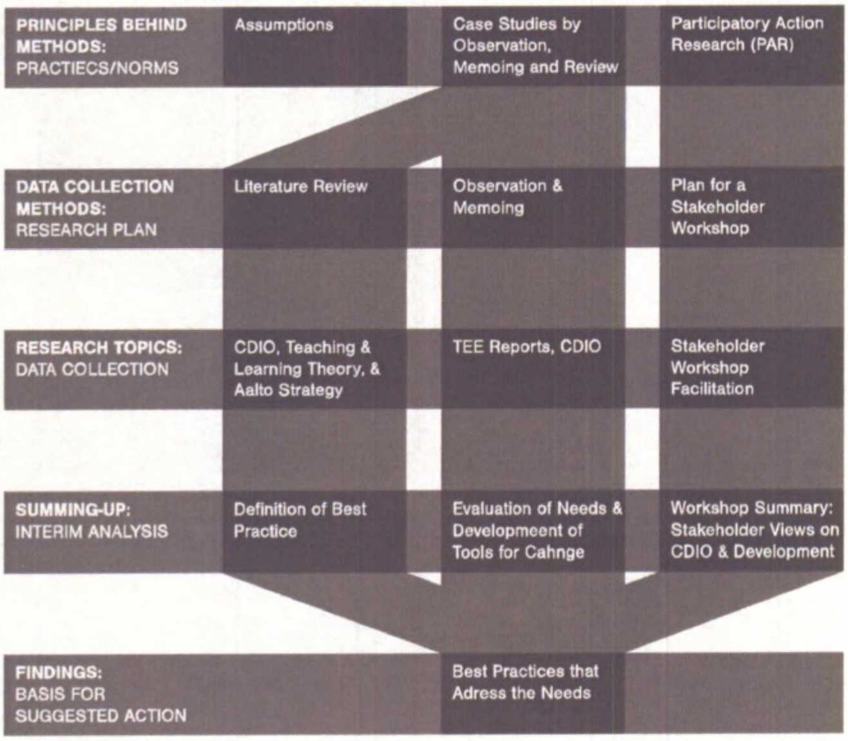

Figure 6 Overview of methods used

An inductive literature review means that the literature review is extended to cover emerging findings during the research; the literature review is integrated into the research, as opposed to being purely a background study of the material (Johnson, et al., 2004). Case study methods are used to get alternative points of view by exploring the contextual environment. PAR is used to involve stakeholders in the process in order to create a sense of ownership for the results and inspire action.

2.1 Assumptions

To lay foundations for the study, a few assumptions must be made (Johnson, et al., 2004). These assumptions will include common general assumptions for educational research, as introduced by Johnson, et al., 2004, as well as some assumptions that are specific to this study. The assumptions of the study are lised below:

- Common general assumptions (as introduced by Johnson, et al., 2004)
    - *There is a world that can be studied. This can include studying the inner worlds of individuals*
    - *Some of the world is unique, some of it is regular or patterned or predictable, and much of it is dynamic and complex*
    - *The unique, the regular, and the complex in the world all can be examined and studied by researchers*
    - *Research should try to follow certain agreed-on norms and practices*
    - *It is possible to distinguish between more and less plausible claims and between good and poor research*
    - *Science cannot provide answers to all questions*
- Assumptions that are specific to this study
    - Future problems that engineers will face are unpredictable
    - Opinions and beliefs that are brought up in this research are valid arguments if they can be seconded or supported by other findings
    - The strategic goals, which have been set by Aalto administration, are a representation of the desired future

- Best practices are practices that are in line with the Aalto Strategy, suggested by the CDIO Initiative, and seconded by theories on teaching and learning

The common general assumptions are there to establish that the combination of psychological and sociological factors can be researched, by studying the unique occurrences, and discovering predictable patterns that are present within a dynamic organisation in an ever-changing environment. The last three points of the common general assumptions establish that science is a human activity that cannot answer moral of philosophical questions. Furthermore, these three points leave room for error and imprecision, which will be discussed when assessing the validity of the research done in this study.

The assumptions guide this study like truths, despite them being open for debate, based on morals, or representative of a philosophical view. The unpredictability of the future is a strongly supported assumption that explains why this study is being done. This fundamental assumption is discussed broadly in Section 1. As this study is firmly based on qualitative research, the second study-specific assumption establishes the well-supported opinions and beliefs will be treated as valid data for the research. In some cases these beliefs and opinions might need to be weighed against each other, therefore strategy can be used to justify answers to some philosophical questions, as established in the third study-specific assumption.

2.2 Literature Review and Case Studies

This study is highly qualitative. The following methods are used for information gathering (Johnson, et al., 2004) (Denzin, et al., 2005):

- A detailed literature review (exploration and definition of best practice)
- Observation (observations during participation)
- Memoing (extracting and sourcing relevant information from reports)

As a form of research, a case study is defined by the interest towards an individual case. The methods of enquiry can be determined quite openly. (Denzin, et al., 2005) For case studies, the methods of enquiry used here are observation and memoing. Observations and memos will be clustered into wholes that are manageable and reasonable case studies.

2.3 Participatory Action Research

One collateral goal of this study is to encourage the establishment of adaptive study programmes. With this in mind, the method of research chosen is participatory action research, hereafter, PAR. The purpose of PAR is to generate practical knowledge that the people involved in the research can use in their everyday lives to contribute to their community (Reason, et al., 2001). Furthermore, PAR is a never-ending and iterative process that is aimed at managing challenges as they come. The PAR cycle is illustrated in Figure 7.

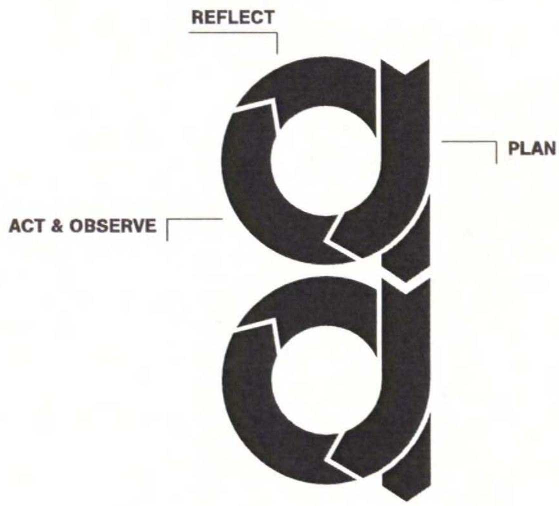

Figure 7 The Action research cycle of self-reflection (based on Denzin, et al., 2005)

In the context of this work, PAR is an iterative and interactive research method that involves the students and teaching staff of KoRa, other stakeholders, and collaborators. In general, the research is conducted by participating in the KoRa teaching improvement initiatives as an observer and reflection catalyst. To get to the desired goals that have been set within the Aalto strategy, it is necessary to get the affected people involved by making them aware of the situation, and inspiring them to take action in the form of collaborative effort that works towards the desired outcomes.

2.4 Data Collection and Interim Analysis

There are many approaches to searching for best practices. Fundamentally, co-creation and exploration are the ways of going about. Co-creation is a way to undertake engineering education reform with a consortium of educational developers from other programmes, departments, or universities. Such collaboration can allow parallel development and sharing of resources (Crawley, et al., 2007). While co-creation is great for synthesising new practices in education, exploration is a more independent process of observation that can lead to the adoption of discovered practices in education.

Because of the highly qualitative nature of the study, the analysis of the information, which is gathered during the study, is an interim process. The elements of the interim process are illustrated in Figure 8.

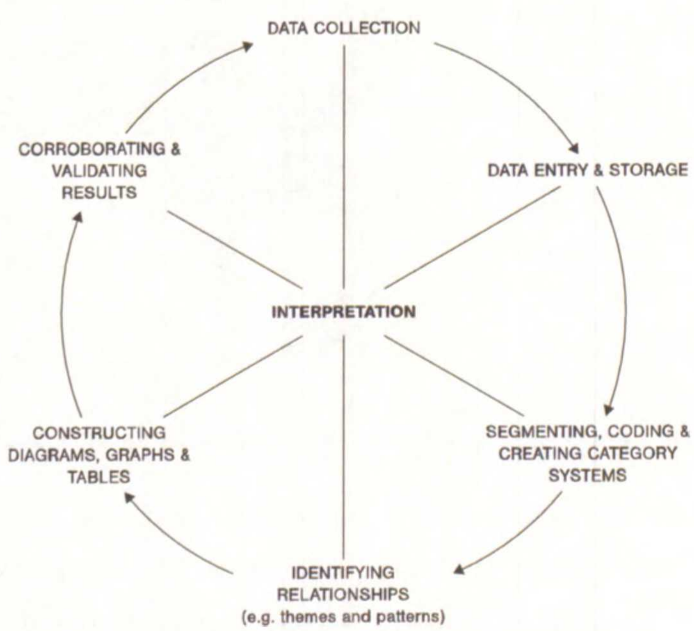

Figure 8 Interim data analysis in qualitative research (Johnson, et al., 2004)

Interim analysis is the act of parallel analysis and data collection, so that data is interpreted and used during the research process and not only after data collection is complete (Johnson, et al., 2004).

2.4.1 Collecting Data by Observation, Memoing and Review

In this study, three case studies and a literature review are used to explore reports and literature, in an interim process of reviewing, note-taking, memoing, and analysing. To understand engineering education, the following topics are reviewed using available literature:

- The CDIO Initiative
- Modern Teaching and Education Theory
- Future Scenarios of Engineering Education

CDIO is built on best practice and collaboration (Crawley, et al., 2007). Therefore, it can be assumed that by exploring best practices within Aalto, which are suitable in the cultural context of KoRa, can be identified. The following topics are observed and sourced for relevant case studies of best practice:

- TEE reports
    - Self-evaluation
    - Panel's report
    - Student feedback
- Personal experience at Aalto
    - As a student
    - As faculty

2.4.2 Collecting Data by PAR: Workshop Planning and Organization

In this study, co-creation is exercised in the form of a workshop that involves focus groups comprising of stakeholders of KoRa as well as people who are familiar with the CDIO Initiative. To actualise PAR in the study, a workshop is planned and executed. The workshop is planned so that it fits the following criteria:

- It is informative
- It is interactive and engaging
- It is a reusable format with varying topics
- It inspires action
- It works for team building

These criteria are inspired by the objectives of this study and are aimed at outlining a PAR workshop format that can be used for the continuous development of education at KoRa while maintaining comparability for use in pedagogical research.

The intended series of PAR activities, for collecting and analysing data, are described in Figure 9. The criterion for successfully conducting the PAR portion of this research is not determined on how faithfully the process is followed; rather, the success of the research is dependent on whether or not the participants have a strong and authentic sense that developments in education can be partially credited to this work (Denzin, et al., 2005).

Organization of the workshop: Before the workshop, questions relating to the findings of the literature review are sent. The sent material is presented in Appendix A. This material is also provided during the workshop.

This particular workshop is a stakeholder workshop. The following stakeholder groups are invited:

- Professors, teaching faculty, educational planner, and department management
- Members of the CDIO community (Tampere Technical University)
- Students
- Industry partners

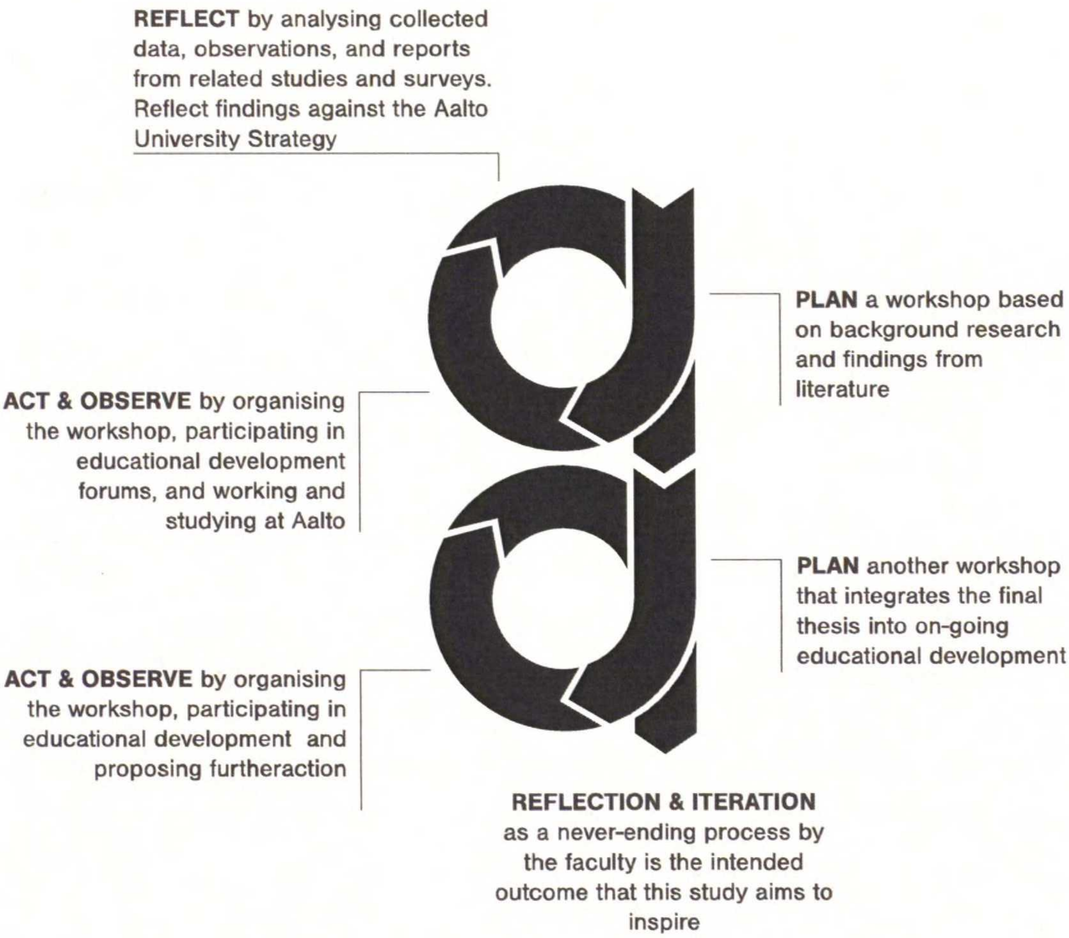

Figure 9 Series of research activities for this study (modification based on Denzin, et al., 2005)

The workshop is organised so, that there are a total of nine small group discussions in spread out into three parts. In the beginning of each part, the participants of the workshop may choose their group freely; however, they need to be evenly distributed into the groups. Each group has 20 minutes for discussion. The nine discussion groups and topics are:

1. **Part 1: Past, Present & Future**
   1.1. **Group 1**: Past: Lessons From The Past:
   1.2. **Group 2:** Present: Lessons from TEE and ongoing educational development initiatives:
   1.3. **Group 3:** Future: Strategic objectives of the future:

2. **Part 2: Integrating CDIO**
    2.1. **Group 4:** Existing Exercise of Interpersonal Skills: What interpersonal skills **<u>are already</u>** integrated into engineering courses?
    2.2. **Group 5:** Integrating Interpersonal Skills: What interpersonal skills **<u>can be</u>** integrated into engineering courses?
    2.3. **Group 6:** A Redesign of the Program Structure: Instead of changing the existing courses to incorporate more interpersonal skill development, can it be done by having the students continuously involved in multidisciplinary projects?
3. **Part 3: Putting the plans to Practice**
    3.1. **Group 7:** Bachelor's Degree Programs
    3.2. **Group 8:** Master's Degree Programs
    3.3. **Group 9:** Working Spaces, Equipment and Services

The group exercises above have two functions: to gather ideas and opinions from the participants, and to provoke thought and create awareness about the issues discussed. This is the PAR element of the workshop (Denzin, et al., 2005).

The date, place and time of the workshop: Wednesday 8.6.2011 at Aalto Design Factory – Audition from 09:00-12:30. During the workshop, lunch is in the form of a teambuilding exercise; an independently functioning barbeque where the workshop participants cook together. After the workshop, the material produced by the participants is collected and analysed. A summary of the results is in Section 4.1. The participants also have an opportunity to give written feedback on the workshop using the forms provided.

3 Literature Review: Defining Best Practice

This section is a look into literature sources that provide criteria for answering the question: what are best practices in engineering education and how are they relevant in the context of mechanical engineering education in Aalto? The theories and literature chosen to approach the study are based on the CDIO Initiative, PBL, and studies that deal with trends and future forecasts in the context of engineering education. The literature resources are chosen to support the objectives of this study. Identification and clarification of best practices in engineering education is supported by literature on CDIO, PBL, and books articles and reports related to teaching in higher education.

3.1 CDIO: Review of Crawley, et al., 2007

Unless otherwise referenced, **this section and its subsections a revision of *Rethinking Engineering Education* by Crawley, et al., 2007**. This is an overview of CDIO that covers the standards and syllabus. There are many elements of CDIO that are brought up in the parts of the study where they are most relevant. In addition to being a central resource for literature dealing with the first objective of this study, the literature surrounding CDIO has been a source of inspiration for the entire study.

The highest level goals in CDIO are three main learning outcomes - educating well rounded engineers who can:

- master deep working knowledge of technical fundamentals
- lead in the creation and operation of new products, processes, and systems
- understand the importance and strategic impact of research and technological development on society

CDIO is a cultural and environmental framework in which disciplinary knowledge as well as practical skills are taught and practiced in order for engineering students to learn how to work in multidisciplinary teams to conceive, design, implement, and operate complete systems. In short, CDIO is a context for engineering education. The CDIO approach is based on stakeholder input, which is used to identify the needs of an engineering programme and to generate deep and integrated learning experiences that meet those needs.

The three goals are the basis for the CDIO learning outcomes, which are defined in the CDIO standards and syllabus. The standards and syllabus are based on a best practice framework that has been developed by identifying the needs for engineering education, and designing a sequence of learning experiences that meet those needs. The result is dual impact learning that promotes deep learning of the technical fundamentals as well as the practical skills set.

The CDIO Initiative promotes the use of modern pedagogical approaches, emerging teaching techniques, and improved learning environments that facilitate real world learning experiences and create a cognitive framework for understanding and retaining the abstractions of the fundamental. This kind of modern educational setting supports activities that allow students to actively apply their knowledge, which, in turn, provides deep working knowledge of the fundamentals. Simultaneously, students experience integrated learning, i.e. parallel development of human, professional, and technical skills.

3.1.1 CDIO Standards

CDIO has 12 standards for guiding assessment and evaluation in order to assure that the three goals above are reached. The standards described here are the outcome or an intensive research process that involved extensive input from different stakeholders groups.

The CDIO standards fall into six categories:

- Programme Philosophy (Standard 1)
- Curriculum Development (Standards 2, 3, and 4)
- PBL and Working Space (Standard 5 and 6)
- Teaching and Learning (Standards 7 and 8)
- Faculty Development (Standards 9 and 10)
- Assessment and Evaluation (Standards 11 and 12)

Standard 1: The Context

The first CDIO standard is having CDIO as the context of engineering education. What it means is that the essence of engineering professions has to be conveyed and practiced in engineering education. The idea is that, while in their degree programme, students are taught to participate in engineering processes, contribute to product development, and work in modern team-based environments.

Standard 2: Learning Outcomes

Technical and disciplinary learning outcomes are programme-dependent. To conform to CDIO, learning outcomes should be linked so that they are consistent with the programme goals. Also, they need to be validated by programme stakeholders. The CDIO framework provides general learning outcomes for technical skills and specific learning outcomes for human and professional skills.

Standard 3: Integrated Curriculum

There needs to be clear integration of human and professional skill-developing elements into the engineering courses, which provide the disciplinary knowledge and technical skills. The idea is not to glue an extra layer of communication, teambuilding, and practical exercises onto a fully scheduled and planned curriculum. The idea is to truly integrate them into the engineering programme so that it makes sense in terms of time, workload, learning objectives and other variables involved in planning.

Standard 4: Introduction to Engineering

The introductory engineering course employs PBL and serves two main purposes: retaining students' interest in engineering as they study the essential scientific fundamentals, and giving the students a cleared idea of what engineers actually do. Engineers design, build, experiment, and work in teams to overcome real-world challenges. These are reasons that bring many people to study engineering. A challenge in engineering education is maintaining the interest of new students. The discharge of mathematics and physics theory onto new students is a big disconcert for many engineering freshmen. It is usually done with the good intention of providing a firm knowledge base of the scientific fundamentals of engineering. However, lack of context and active learning results in students giving up on engineering, or completing the fundamental courses with minimum requirements and gaps in their knowledge.

Standard 5: Design-Implement Experience

Much like the previous standard, this is a PBL approach to supporting learning in the knowledge-intensive technical and scientific courses. While the introductory element is the main point of the previous standard, this standard establishes that it is ideal to have design-implement experiences through the duration of the degree programme. This kind of PBL exposure supports the essence of engineering.

Standard 6: Engineering Workspaces

The school facilities need to support and encourage hands-on learning in teams in environments that have spaces to support ideation, engineering design, prototyping, and testing. The facility should also cater for social interaction, personal learning, and, if possible, flexible access to tools and access beyond normal working hours.

Standard 7: Integrated Learning experience

Much like Standard 3, this standard advocates the concurrent development of disciplinary knowledge with human and professional skills. This standard emphasised the experience of integrated learning. Engineering skills are not to be separated from professional and human skills; they should not be perceived as distant from each other by the students. The engineering faculty act as role models who train the students in human and professional skills, in addition to the engineering disciplines. The faculty's competence as role models is incorporated in Standards 9 and 10.

Standard 8: Active Learning

Students learn better when they are engaged in the learning activity (Fry, et al., 2003). Figure 29, on page 56, shows how student commitment is higher, for both academic and non-academic students, when active learning is applied (Hyppönen, et al., 2009). CDIO encourages the engagement of students in hands-on project-based learning with less lecturing and more guidance.

Standard 9: Enhancing of Faculty Skills Competence

The skill set of the graduates tends to be a reflection of the faculty's skill sets. Therefore, the faculty need to possess the skills that are in intended learning outcomes – professional and human skills included. Because some of the academic staff tends to be from a research background and have less experience in practicing engineering in an enterprise context, they may not be able to properly guide students in the development of professional and human skills. The CDIO programme provides opportunities for faculty members to participate in training that will enhance their skills in the CDIO context. Faculty needs to be able to act as role models and guides for developing students' knowledge and skills by using integrated teaching methods.

Standard 10: Enhancing of Faculty Teaching Competence

The quality of teaching, integrated learning experience, and effective assessment are in the hands of the teaching faculty. For this reason, the CDIO programme also offers pedagogical training that helps faculty enhance their competence in the creation of an integrated learning experience, defining and assessing learning outcomes, and choosing appropriate teaching, which engage in active learning.

Standard 11: Learning Assessment

Assessment has two main roles: to support learning by allowing reflection, and to act as a measure of learning achievement. It can be used to adjust learning outcomes as well. When planning courses, assessment is one of the three corner stones, the other two being learning outcomes, and teaching activities.

Standard 12: Program Evaluation

Continuous evaluation and improvement is essential to CDIO. Figure 10 illustrates the constant development process. The idea is to have a programme reform that is dynamic and responds to future changes. The programme should continue to develop with the help of periodical evaluation and stakeholder input. After the programme is reformed the entire cycle can be re-implemented to assure an up-to-date engineering programme.

3.1.2 The CDIO Syllabus

In the CDIO syllabus, human skills are separated into personal and interpersonal skills. Furthermore, personal and professionals skills are combined. To avoid confusion of terminology for describing skills, see Figure 11.

The CDIO syllabus defines the personal, professional, interpersonal, and CDIO context-related skills that are meant to be integrated into the teaching of disciplinary knowledge that is defined by an engineering programme's faculty.

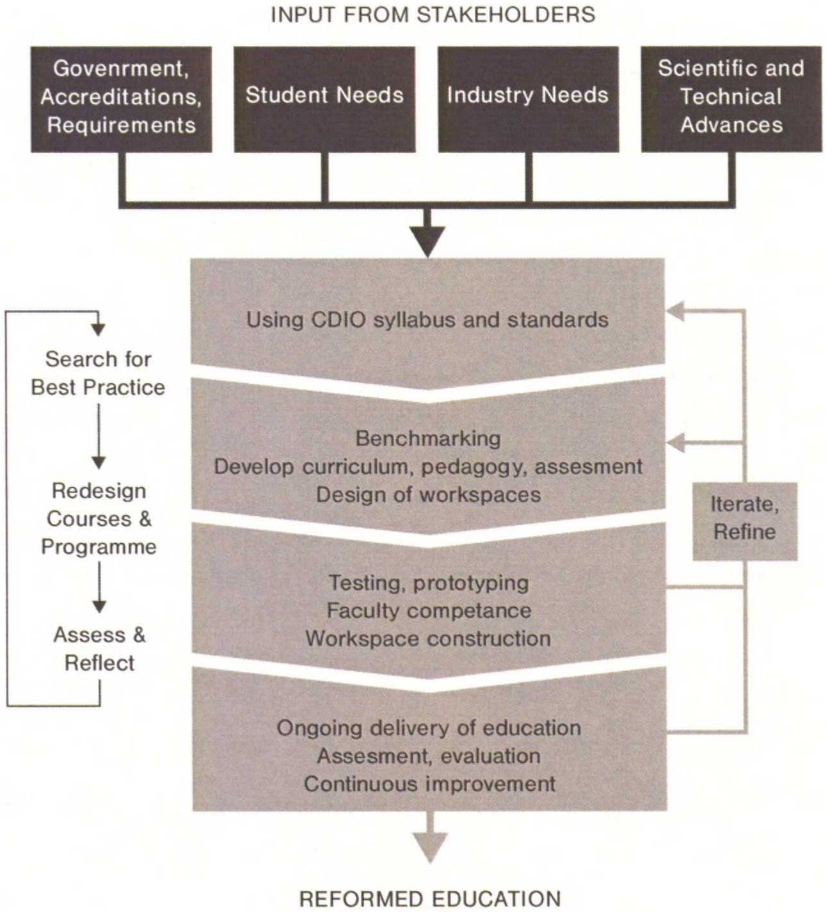

Figure 10 Design and Development of the CDIO approach (based on Crawley, et al., 2007)

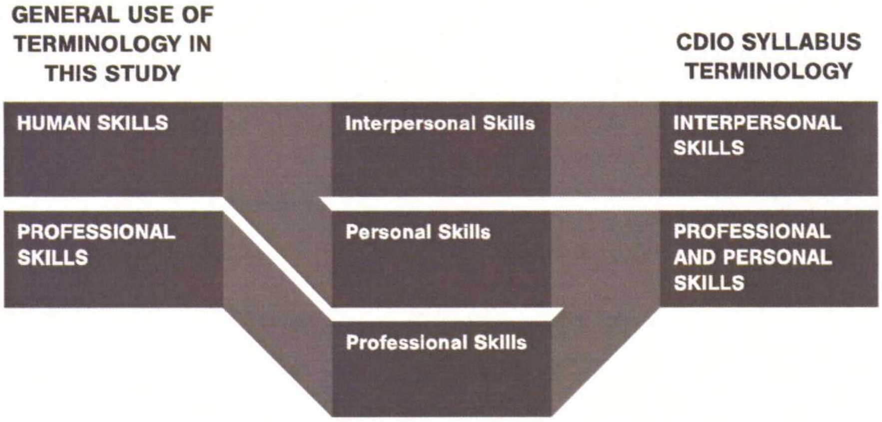

Figure 11 Differenced in use of terminology for skills

The syllabus has three levels. The top level consists of four points as illustrated in Figure 12. Engineers should have technical knowledge and reasoning (1), personal and professional skills (2), and interpersonal skills (3) that they are capable of applying in an enterprise, societal and environmental context (4).

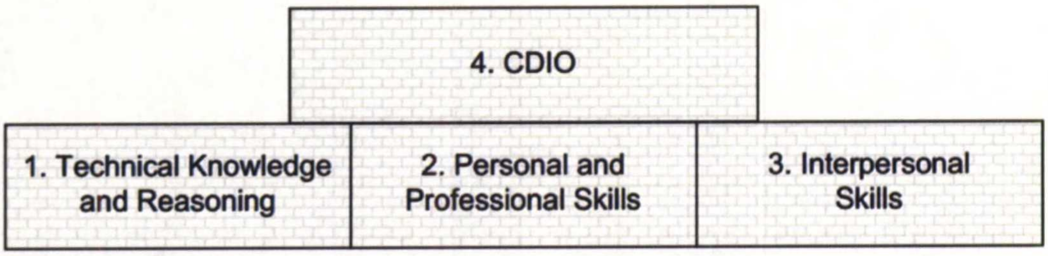

Figure 12 Essential building blocks of knowledge, skills, and attitudes in the CDIO Curriculum (Crawley, et al., 2011)

The second level of the syllabus opens 17 sections under the previous four (Figure 13). Engineering professions rely on the underlying mathematical and physics principles (1.1) that support the core engineering fundamentals (1.2), which are the roots of the advance engineering methods and tools (1.3) that we use today.

For engineers, there are three commonly practiced modes of thought: analytical reasoning and problem solving (2.1), experimentation investigation and knowledge discovery (2.2), and system thinking (2.3). Personal values relating the professionalism are ethics, equity and responsibility (2.5). Personal values that are not directly linked to responsibilities are attitudes, thought, and learning (2.4).

Engineers need to be capable of teamwork (3.1) in a modern, team-based environment, and therefore, they should have good interpersonal skills. Interacting with others requires competence in communications (3.2). Furthermore, interacting in an international context can have significant benefits if skills in foreign languages (3.3) are practiced.

4. Applying Knowledge and Skills in the Enterprise, Societal and Environmental Context

4.1. External, Societal, and Environmental Context
4.2. Enterprise and Business Context
4.3. Conceiving, Systems Engineering and Management
4.4. Designing
4.5. Implementing
4.6. Operating

1. Disciplinary Knowledge and Reasoning	**2. Personal and Professional Skills and Attributes**	**3. Interpersonal Skills: Teamworking and Communication**
1.1. Knowledge of Underlying Matematics and Science	2.1. *Analytical Reasoning and Problem Solving	3.1. Multi-disciplinary Teamwork
1.2. Core Engineering Fundamental Knowledge	2.2. *Experimentation, Investigation, and Knowledge discovery	3.2. Communications
1.3. Advanced Engineering Fundamental Knowledge, Methods and Tools	2.3. *System Thinking	3.3. Communications in Foreign Languages
	2.4. **Attitudes, Thought, and Learning	
	2.5. **Ethics, Equity, and Other Responsibilities	

* Professional Skills
** Personal Skills

Figure 13 Second level of the CDIO syllabus (based on Crawley, et al., 2011)

Graduates are more competent if they graduate with a good sense of what to expect from the real world. This can be achieved by graduating engineers that have had opportunities within their studies to implement (4.3) fully functional and operable (4.4) complex systems that have been conceived (4.1) and designed (4.2), in a multidisciplinary team.

Further levels of the teaching and knowledge block (1) are not defined by the CDIO syllabus, since they are unique for each engineering discipline. On the other hand, the CDIO syllabus defines the remaining three blocks with a third level of detail. The detailed syllabus is attached in Appendix C.

3.1.3 Steps to Initiating CDIO

Implementation of a CDIO program will require cooperation from all faculty members of KoRa. Twelve key success factors facilitate the organisational change while reforming an engineering program to conform with CDIO standards. The key success factor for implementing a CDIO complient curriculum are divided into three phases of change: getting off to the right start, building momentum in the core activities of change, and institutionalising change. The key success factor are listed under their respective phases below:

- Getting off to the right start
    - Understanding the need for change
    - Leadership from the top
    - Creating a vision
    - Support of early adopters
    - Early sucesses
- Building momentum in the core activities of change
    - Moving off assumptions
    - Including students as agent of change
    - Involvement and ownership
    - Adequate resources
- Institutionalising change
    - Faculty recognition and incentives
    - Faculty learning culture
    - Student expectations and academic requirements

Step 1: Getting Started

When getting started, understanding the need for change is essential to stimulating and motivating change. This goes hand-in-hand with the creation of a common vision that functions as an organising theme of the work being done by the faculty, as a foundation for creating involvement and ownership, and as the key motivator for working towards the desired changes.

Additionally large-scale social shifts are capable of providing a context in which change is easier. Also, when getting started, leadership from the top is necessary for getting formal support, especially for the early adopters who are more incline to try new approaches in a change resisting environment. Supporting early adopters will lure out the dormant and shy ideas. Even with everybody on the same page and the scales tipping in favour of change, it should be kept in mind that action inspires action. Therefore, there need to be early signs of success, which means implemented instances that work. Early success and the first action are the final efforts required to overcome the static friction of resistance to change, and to get the movement going.

Indicators:

- Faculty understands the need for change
- Leadership from the top is involved
- There is a clear vision in the form of a mission statement, theme, strategy, or general understanding within the faculty
- Early adopters get support for experimental advances in teaching and learning
- There is an initiative that has sucessfully proven that new changes generate results

Step 2: Building Momentum

When redesigning the curriculum, there should be a clean platform to build on, without assumptions creating imbalance and restriction that will limit the maximum potential of new ideas; the rules and restrictions should be forgotten for a while. Setting assumptions aside is a skill. A professional engineer should be able to adopt this attitude when conceptualising novel ideas.

Students are naturally good collaborators in the change process, since they are less likely to have well-grounded assumptions or attitudes in regard to the activities of the faculty. On the other hand, students may be afraid of changes that may affect their study plans. This fear may be overcome by making change a known part of the engineering education programme. As long as there is some consistency in the programme's overall learning outcomes, constant changes, which continuously work to improve the attainment of learning outcomes, are mostly positive things. A good analogy would be constantly updated software.

It is important to have early involvement of the people, or at least representatives of groups of people, that is influenced by education reform. The idea is to have everybody involved to be satisfied with, if not enthusiastic about, the planned changes. If the whole community has a sense of ownership of planed reforms, the change process can be a lot smoother. Involvement should not be a one-off meeting, it needs to be engaging, and it should allow time for reflection and debate. For the whole process to proceed smoothly, an occasional boost of resources can help in the actualisation of many ideas. Without additional resources, the effect of a resource boost might be achieved by collaborative efforts to join resources.

Indicators:

- The faculty recognises that putting assumptions aside is a skill that they could and should harness as professionals
- Students are a part of the process and promote change
- Everybody concern is involved, and has a chance to participate
- There are occasional resource boosts that motivate and accelerate, alternatively, new collaborative efforts simulate temporary resource boosts

Step 3: Institutionalising Change

In any organisation, you get the behaviour that is rewarded. On the other hand, some studies show that increased monetary rewards may not induce the desired outcome if salaries are at an acceptable level (Pink, 2009). Nonetheless, in terms of general resources for teaching and learning at KoRa, it can be assumed that rewards result in wanted behaviour. It is brought up in the TEE self-evaluation that resources are insufficient in a lot of cases (Aaltonen, et al., 2011). Given the current situation, rewarding early adopters with additional resources can improve the general climate for taking initiative.

There needs to be a general consensus that learning is the centre driving purpose for the department's activities. Lifelong learning is a philosophy that should be adopted and the faculty is in the role of setting an example. Since the university's role is to produce new knowledge, lifelong learning is essential to live up to this promise. By adopting the desired attitudes and philosophies, communicating them to the students is important on all levels: the first impression, the informal expectations, and the formal intended learning outcomes.

Indicators:

- The faculty takes initiative and management reward the strategy-supporting initiative with sufficient resources
- Faculty members are lifelong learners and education is learning-centred
- Expectations and requirements are, more or less, obvious

Barriers to Change arise when introducing new teaching methods. Introducing these new methods is commonly more threatening to faculty than reforming the curriculum. There are five common barriers to implementing active and experiential learning:

1. Lack of coverage
2. Increased faculty preparation time
3. Large class sizes
4. Lack of resources
5. Risk to the faculty member

Teachers get concern when all the material that they want to teach is not covered. This concern can partly be overcome by stressing learner-centric education; emphasis on student learning (and the big picture behind their degree programme) rather than "teaching the way that it has always been taught". For the second concern to be tamed, faculty simply need to be given more time and resources to change and develop their teaching. This communicates that development is important and valued.

Development in teaching can also be motivated in the hiring procedure. Aalto is implementing this strategy by increasing the appreciation for pedagogical skills during the hiring process (Aalto University Strategy, 2011).

3.2 Change Brought by Aalto University

Change in engineering education has been a hot topic of discussion during the past century (Ernst, et al., 1998). However, is has been rather time and resource consuming for individual educators to drive change forward (Crawley, et al., 2007). Collaborative efforts are the best way to get started with CDIO. It is in the interest of the CDIO community that the network expands. Finding collaborators or open-source resources has been made easy.

This section also introduces the circumstance of machine design education in Aalto. The circumstances are based on the Teaching Evaluation Exercise, existing research on education at KoRa, the history of TKK[5], and the Aalto strategy.

Aalto is constantly evolving in order to respond to the changing world. To monitor change and respond to it, the university management has initiated questionnaires, evaluation exercises, workshops, action groups, and so forth. These initiatives and forums are important because they start and sustain discussion about the good practices and shortcomings of the status quo, as well as the threats and possibilities of the future. Because Aalto is a fairly recent occurrence, the rate of change within the university is very fast-paced and chaotic. This challenging state is taken advantage of by this study, in the sense that there is currently a need and an opportunity to define the context of mechanical engineering education in Aalto.

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[5] TKK is an abbreviation of Teknillinen korkeakoulu, which is the Finnish name for the Helsinki University of Technology, the organisation that was made up of the current four Schools of Science and Technology in Aalto University

As the Aalto strategy defines the context in which its schools will operate, it contributes to the definition of "the context of mechanical engineering education in Aalto."

By aiming to find adoptable best practices in mechanical engineering education this study takes advantage of the opportunities that have resulted from the Aalto merger:

- **Interest of the industry**, verified by the extent of donations (Aalto-www Fundraising, 2012)
- **Growing efforts to become more international**, verified by the activities of Aalto's student s, the Global Design Factory Network, and the Aalto Strategy.[6]
- **Increased interdisciplinary opportunities in education and research** (Aalto-www Multidisciplinary, 2011), verified by the increasing activity within the Factories, which serve as platforms for interdisciplinary collaboration and experimentation.

3.2.1 The Past, Present, and Future of Engineering Education at KoRa

Both CDIO and the Aalto strategy advocate the education of engineers who are valuable to the society (Aalto University Strategy, 2011) (Crawley, et al., 2007). In the Aalto strategy, it is clearly stated that the role of the university will be to produce knowledge for the society. Simultaneously, *"the goal is to advance the welfare and competitiveness of the Finnish nation as well as to support and nourish culture, creativity and education."* (Aalto University Strategy, 2011).

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[6] The Aalto University's students have organised *Aalto on Tracks* (http://aaltoontracks.com/) and *Aalto on Waves* (http://www.aaltoonwaves.com/), two revolutionary student initiatives that are likely to have similar successive initiatives (Aalto on Waves, 2012).

"The global network consists of Design Factories that operate based on the same principles and philosophies and also provides the same familiar environments to operate in. Currently the network reaches and is present in Shanghai (Aalto-Tongji Design Factory), Melbourne (Swinburne Design Factory) and Finland (Aalto Design Factory)." (Tuulos, 2012)

"Ignorance of an organization's past can undermine the development of strategies for its future" (Mintzberg, et al., 2001)

TKK has played a significant part in Finland's history of modernisation. In the middle of the 19th century, Finland's domestic industrial production began to grow as a result of the technology transfer system established by the Finnish government. Technical education, which was a major component of the industrial growth, began to expand and change society. (Nykänen, 2008)

Around the change of the millennium, the intensification of research in secondary technical education sparked further debates about the roles of the two levels of institutes. As a result, leaders of the state demanded that universities should reach top-level standards in research and education. The demands began to be met as new high-tech branches were adopted as rapidly developing disciplines of the future. The shift of the role of universities began. (Nykänen, 2008)

Today, the university is working to adapt to the effects of globalisation: people, investors, and industries have been working globally, production has been pursuing cheap labour, and the everyday work of scientist has become very reliant on the internet and e-mail. Another trend that has been having an effect on the university is the rising need for knowledge that lies on the borderlines of disciplines. As this was realised, the intense collaboration between TKK, the Helsinki School of Economics, and the University of Art and Design Helsinki, turned into plans for a merger. (Nykänen, 2008)

Aalto University was established in January 2010, when the Helsinki School of Economics (est. 1911), the University of Art and Design Helsinki (est. 1871), and the Helsinki University of Technology (est. 1849) merged as shown on the timeline in Figure 14. Aalto University School of Science and Technology was then divided into four new schools of technology in January 2011.

Aalto currently consists of six schools and some additional units (Aalto-www Organization, 2012):

- School of Arts, Design and Architecture (Aalto ARTS)
- School of Chemical Technology (Aalto CHEM)
- School of Economics (Aalto ECON)
- School of Electrical Engineering (Aalto ELEC)
- School of Engineering (Aalto ENG)
- School of Science (Aalto SCI)
- Other Units

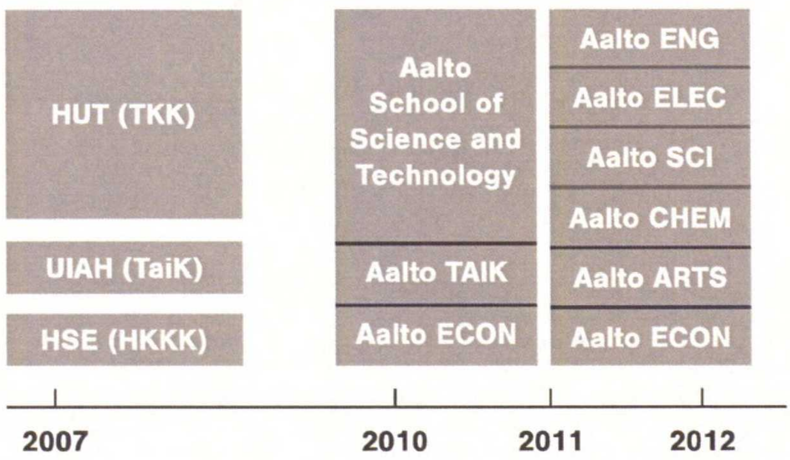

Figure 14 History and structure of the Aalto merger.

In 2012 Architecture moves from Aalto ENG and merges with Aalto TAIK to form Aalto School of Arts, Design and Architecture. With these changes in place, and plenty more under works, Aalto provides a great context for reform.

Engineers today need to tackle new kinds of problems by using non-standardised social and technical processes, and combinations of interdisciplinary knowledge. The fundamentals need to be mastered, and expertise in technology is also essential. However, science and technology alone are not enough. Engineers need to understand the broad context of their work; if engineering is supposed "*to advance the welfare and competitiveness of the Finnish nation as well as to support and nourish culture,* *creativity and education,"* (Aalto University Strategy, 2011) engineers need to take responsibility for social, economic, and environmental implications of technology. (Korhonen-Yrjänheikki, 2011).

If engineering education could live up to these requirements, the future engineers will be very capable of addressing grand challenges. The content of Table 1 is a collection of past engineering achievements and future engineering challenges.

The challenges rationalises the pursuit for developing problem-based and interdisciplinary engineering education that will contribute to the resolution of the listed problems and challenges. The greatest achievements of the 20th century tell a lot about our past. Correspondingly, the future challenges and future problems can help us determine the future requirements for engineering graduates. The technologies and challenges that are listed in Table 1 all have something in common – they are complex systems or require expertise from multiple disciplines to be overcome.

The 20th century was all about technological advancement, and this is eminent from the NAE's lists of the advancements, which includes technologies such as electricity, cars, planes, clean water, telephone, computers, and internet. These technologies improved the living conditions for many people as intended to, however, unintended outcomes of these technologies have been positive and negative influences that have brought about some of the 14 grand challenges that the NAE has recently set for the 21 Century. (Grasso, et al., 2010)

PBL in engineering education is also rationalised by the mysterious nature of the "right answers" to the 14 grand challenges or to the 20 global problems. The 14 grand challenges are technical and scientific puzzles that need to be solved in order to satisfy the growing needs of the expanding population, while improving the quality of life, and protecting humanity from natural disasters and manmade threats (U.S. National Academy of Engineering, 2008). These are not to be confused with the 20 global problems introduced by Rischard (2002), which are also very relevant to the education of future engineers.

Table 1 Greatest achievements, future challenges and future problems

Greatest Engineering Achievements of the 20th Century (NAE)[7]	14 Grand Challenges of Engineering for the 21st Century (NAE)[8]	20 Global Problems, 20 Years to Solve Them (Jean-Francois Rischard)[9]
1. Electrification 2. Automobile 3. Airplane 4. Water Supply and Distribution 5. Electronics 6. Radio and Television 7. Agricultural Mechanization 8. Computers 9. Telephone 10. Air Conditioning and Refrigeration 11. Highways 12. Spacecraft 13. Internet 14. Imaging 15. Household Appliances 16. Health Technologies 17. Petroleum and 18. Petrochemical Technologies 19. Laser and Fibre Optics 20. Nuclear Technologies 21. High-performance Materials	1. Make solar energy economical 2. Provide energy from fusion 3. Develop carbon sequestration methods 4. Manage the nitrogen cycle 5. Provide access to clean water 6. Restore and improve urban infrastructure 7. Advance health informatics 8. Engineer better medicines 9. Reverse-engineer the brain 10. Prevent nuclear terror 11. Secure cyberspace 12. Enhance virtual reality 13. Advance personalized learning 14. Engineer the tools of scientific discovery	Sharing our planet: Issues involving the global community 1. Global warming 2. Biodiversity and ecosystem losses 3. Fisheries depletion 4. Deforestation 5. Water deficits 6. Maritime safety and pollution Sharing our humanity: Issues requiring a global commitment 7. Massive step-up in the fight against poverty 8. Peacekeeping, conflict prevention, combating terrorism 9. Education for all 10. Global infectious diseases 11. Digital divide 12. Natural disaster prevention and mitigation Sharing our rule book: Issues needing a global regulatory approach 13. Reinventing taxation for the twenty-first century 14. Biotechnology rules 15. Global financial architecture 16. Illegal drugs 17. Trade, investment, and competition rules 18. Intellectual property rights 19. E-commerce rules 20. International labour and migration rules

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[7] http://www.engineeringchallenges.org

[8] The National Academy of Engineering (NAE) listed the top technological achievements[8] of the 20th century. Recently, the Academy published a list of 14 grand challenges of engineering for the 21st century. http://www.greatachievements.org.

[9] Jean-Francois Rischard; economist, vice president of the World Bank Europe 1998-2005, author of *High Noon 20 Global Problems, 20 Years to Solve Them* (Rischard, 2001)

It can be argued that the future of engineering advancement will not be limited by technology, but rather by the creative extent of the mind, due to a phenomenon known as the Technological Singularity. (Kurzweil, 2005)

3.2.2 Strategy, Structure and Scale of Aalto University

The fundamental role of academic staff is to plan and execute teaching and learning. Therefore, the academic staff is expected to have an understanding of the institution's culture, which is defined by the mission and vision of the institution. Inevitably, the curriculum is influenced by the aspiration, ethos and values of the institution's culture. (Fry, et al., 2003) The culture of Aalto is defined by its strategy.

To better moves and inspire people, communicating the strategy should start by explaining the underlying principal behind the strategy (why), then by elaborating on the details that bridge the principles and reality (how), and finally by stating the tangible actions points for implementing the strategy (what). The model that explains this order of delivering a message is known as the golden circle Figure 15 (Sinek, 2009).

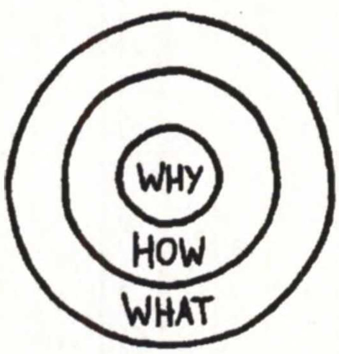

Figure 15 The golden circle: Inspirational messages are communicated from the inside out, starting with why. (Sinek, 2009)

Aalto has two main points in the mission statement: to strengthen the Finnish innovation system (Figure 16), and to work towards a better world (Figure 17). The vision being worked towards is the status of an institution internationally recognised for the impact of its science, art and learning. All this is to be done while preserving the Aalto values: passion for exploration, freedom to be creative and criticality, courage to influence and excel, responsibility to accept, care and inspire, and integrity, openness and equality. (Aalto University Strategy, 2011)

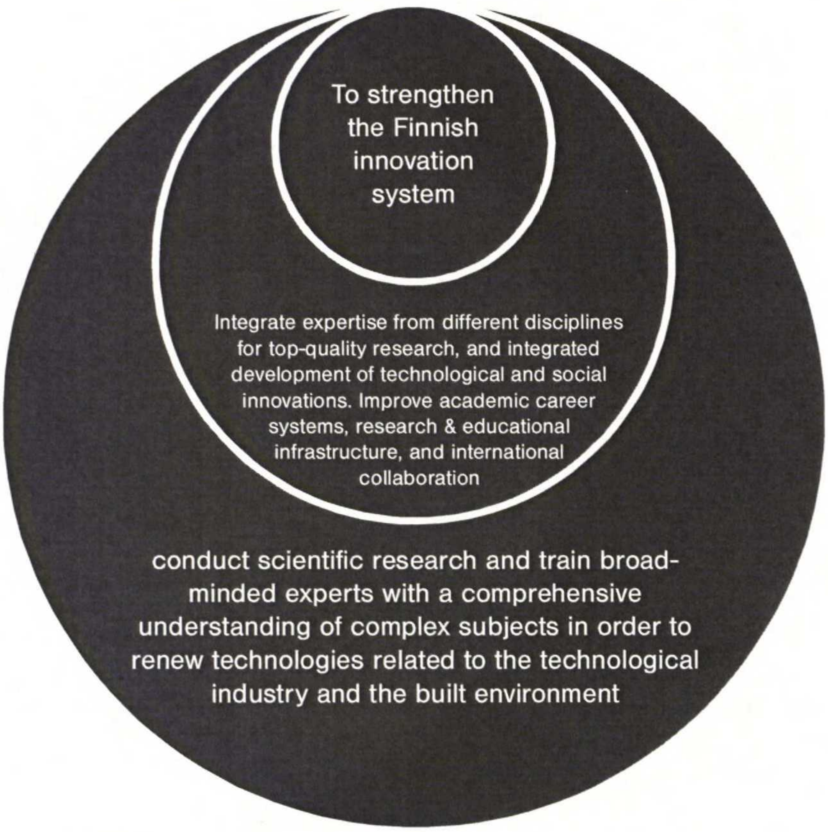

Figure 16 Golden circle of Aalto's mission statement on strengthening the Finnish innovation system. The outer circle (the "what?" circle) is written for Aalto ENG.

The establishment of Aalto stems from national strategy. The Finnish University Reform, which is an underlying national strategy behind the establishment of Aalto, is put together in order to strengthen the Finnish innovation system by integrating expertise from different disciplines (Figure 16).

Each of Aalto's six schools exhibit strengths and areas of research developed through a long history. The strategic focus of the school of engineering is on research areas covering the entire built environment, its machines, and equipment. (Aalto University Strategy, 2011)

Figure 17 Golden circle of Aalto's mission statement working towards a better world. The outer circle (the "what?" circle) is written for Aalto ENG.

The main task of the school of engineering is to (Aalto University Strategy, 2011):

- Conduct scientific research and train broad-minded experts with a comprehensive understanding of complex subjects in order to renew technologies related to the technological industry and the built environment
- Create research-based knowledge and new solutions to serve the goals of sustainable development.

Strategic points on education are communicated very comprehensively in the Aalto Strategy. The strategic objective in education is to maintain academic freedom, and achieve high international quality and recognition. (Aalto University Strategy, 2011)

This is to be done by creating an inspiring, professional community that encourages lifelong learning, promotes a culture of creativity and entrepreneurship, and improves the skills of students for entering professional life. The following five key areas, listed in the bottom Figure 18, should be developed to facilitate the desired occurrences (Aalto University Strategy, 2011).

Figure 18 Golden circle of Aalto's core strategy for education.

The surrounding world is changing as economic development is increasingly based on expertise rather that resources, globalisation is taking place, environmental conditions are changing, and technological development is accelerating. As a result, the reassessment of universities roles is a global phenomenon which is driving universities to become ever more central to society as producers of new knowledge that learn from, interact with, and serve their surrounding community. (Aalto University Strategy, 2011)

Challenge and potential arises from the need to adapt. Figure 19 is a SWOT analysis of Aalto's academic environment and it is based on the second chapter in the Aalto strategy, which describes the challenges and opportunities in the academic environment. The school-specific strengths for Aalto ENG have been included in the SWOT.

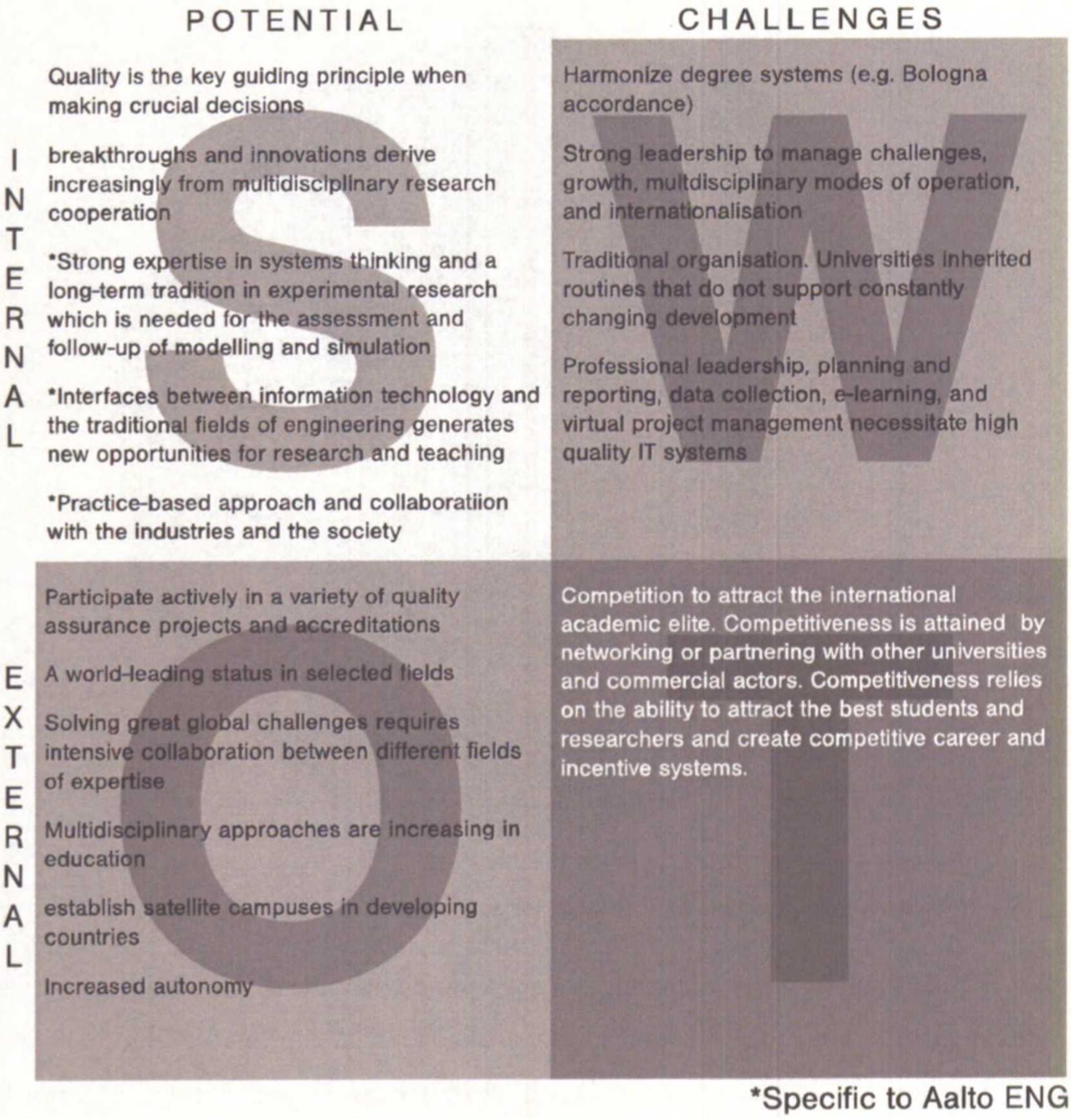

Figure 19 SWOT of Aalto's academic environment based on the Aalto strategy (Aalto University Strategy, 2011)

3.2.3 Structure of KoRa's Programmes

The objectives of the Mechanical Engineering Programme is to provide the highest level of education in the field, and to create competence and scientific knowledge that will be exploited through active collaboration with the society and the industry. Students should be able to acquire a broad education by combining different modules and adding courses from other schools into their degree. The intention is to equip students with the competence and understanding that is required for performing technical and scientific tasks, continuously developing to meet the requirements for working in the chosen field, and applying creativity and scientific advancements in practice. (Jokela, et al., 2012)

The structure of KoRa's degree programmes is undergoing major changes at the moment. Incorporating these changes may improve the relevance of this work significantly.

KoRa offers BSc and MSc degrees in mechanical engineering. For nearly all departments in Aalto's schools of technology, the degree is based on a modular structure as shown in the left hand side of Figure 20. In that modular structure, the lower block (modules P, O, A1, A2, B1, V, and K) add up to the BSc degree, and the upper block (modules A3, B2, W, M, C, and D) compose the MSc degree. A detailed version of the module structure is in Figure 21. (Jokela, et al., 2012)

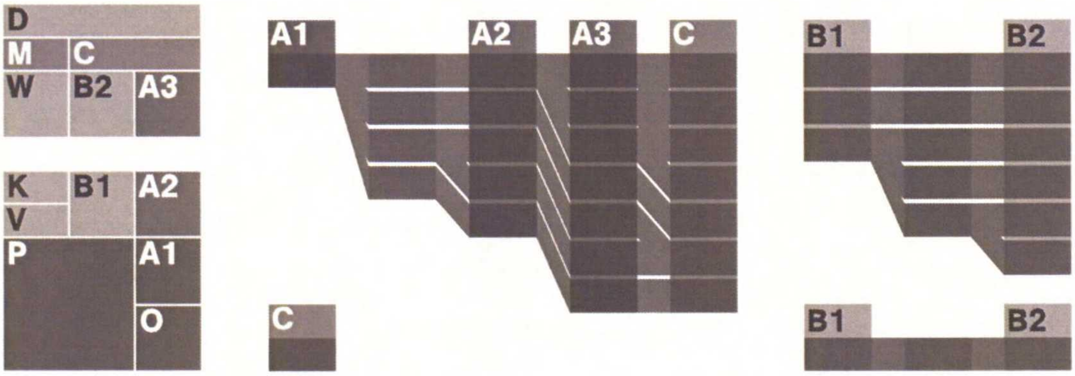

Figure 20 Modular Structure of KoRa's Degree Programme (based on figures and guidelines by Jokela, et al., 2012)

Students at KoRa choose one of the majors offered by KoRa, and a minor offered by Aalto's Schools or any other university from the long list of collaborating universities. The major is a combination of four modules: A1, A2, A3, and C. The middle diagram in Figure 20 represents the main alternative branches of majors offered for students at KoRa. Minors (modules B1, and B2) offered by KoRa are mainly for students with majors in different fields. A detailed version of the middle diagram is in Figure 22. The diagram in the right hand side of Figure 20 represents the alternative branches of minors offered by KoRa. The individual occurrences of the C-module and the B1 and B2 modules, in the bottom of Figure 20, represent the flexibility of having external studies in those modules. A detailed version of the right-hand-side diagram is in Figure 23. (Jokela, et al., 2012)

Prior to 2005, the educational structure of KoRa was made up of a two-cycle process: Master and doctorate. The Master's programme was designed to be continuous five year programme that included of BSc-level and MSc-level studies, and ended in an MSc degree. The students had the possibility to choose a major from KoRa's list of offered majors, and a minor from virtually any department or another university.

Over the course of 2005 and 2010, the programme structure has been renewed to conform to the three-cycle process: Bachelor, Master, and doctorate. Figure 21 shows the breakdown of the Bachelor's and Master's cycles. Besides the inclusion of a Bachelor Thesis and seminar, the overall structure of the current programme is very similar to that of the programme prior to 2005. (Kuusela, 2004) (Jokela, et al., 2012)

The major tracks and minor tracks offered to KoRa students offer a lot of variety. As mentioned earlier, the major is a combination of four modules: A1, A2, A3, and C. The branches for each major are depicted in Figure 22. All majors have a common basic module (A1), Basic Engineering Design and Production, which is completed in the BSc cycle of the degree programmes. (Jokela, et al., 2012)

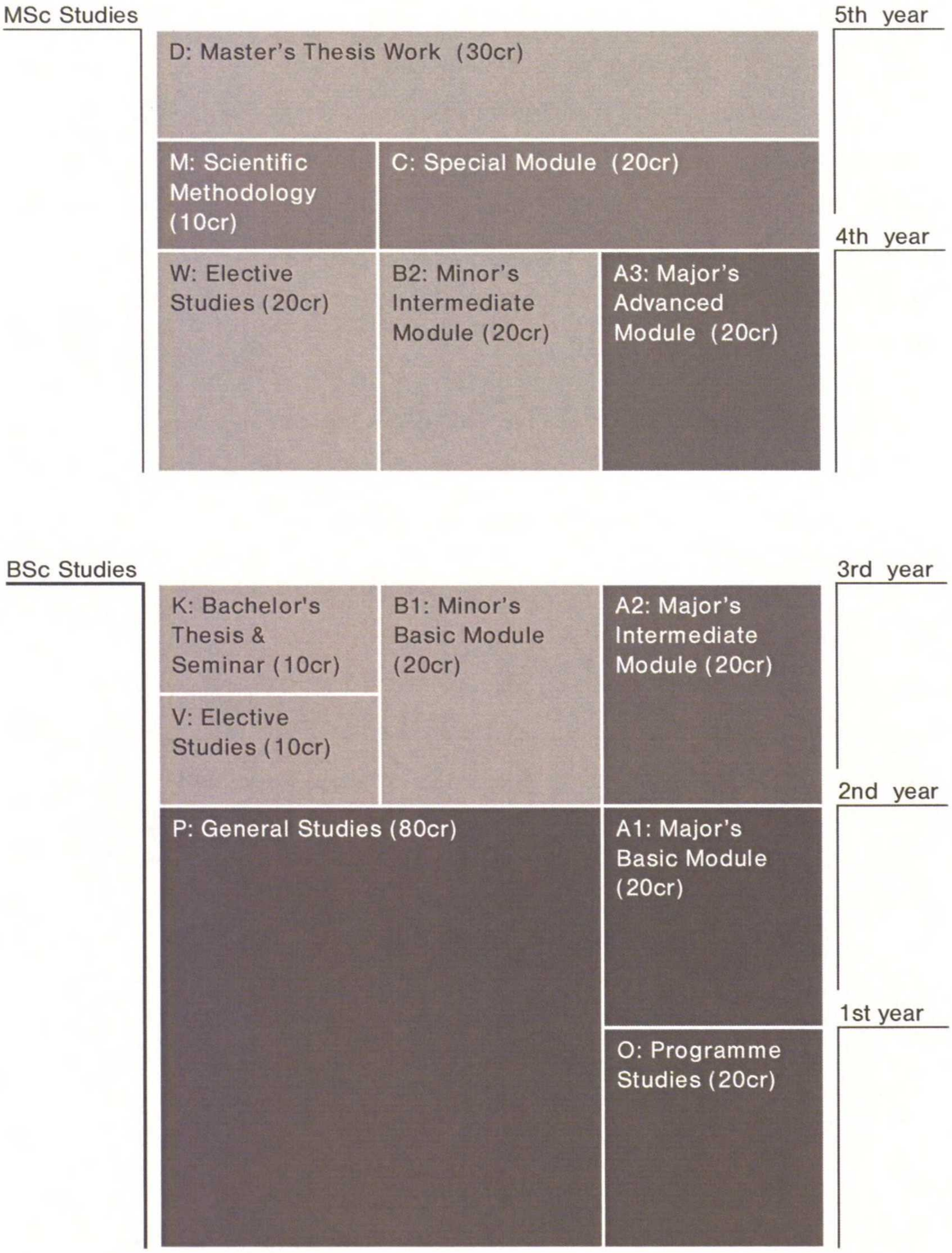

Figure 21 Module Names and Positions (based on figures and guidelines by Jokela, et al., 2012)

Each major has one intermediate module (A2), with the exception of Production Technology, where specialisation takes place at an earlier stage, resulting in two alternative intermediate modules: Production Technology, and Foundry Technology. Also, Future Industrial Companies (Framtidens Industri Företag, or FIF), is an exception structurally, since it is a joint programme with other Nordic universities and has no formal A2, A3, and C modules. Material Science in Mechanical Engineering offers only one major track. In Machine Design, specialisation takes place during the advanced module (A3). Machine Design branches out into three different fields: Vehicle Engineering, Product Development, and Mechatronics and Hydraulics. (Jokela, et al., 2012)

The special module (C), is a flexible module within certain restrictions; it is an opportunity for students to specialise further within their own field, or to direct their expertise towards the junction of their own field and another field (Jokela, et al., 2012).

The minors offered by KoRa are on five different tracks as shown in Figure 23. Mechatronics has specific modules, basic (B1) and intermediate (B2), for a minor in mechatronics. Product Development has a flexible basic module (B1) and an advanced (notice, not intermediate) module (B2). (Jokela, et al., 2012)

Machine Design, Material Science in Mechanical, Engineering, and Production Technology minors all share the same basic module (B1), Engineering Design and Production, which is identical to the basic module (A1) that is part of the KoRa majors. (Jokela, et al., 2012)

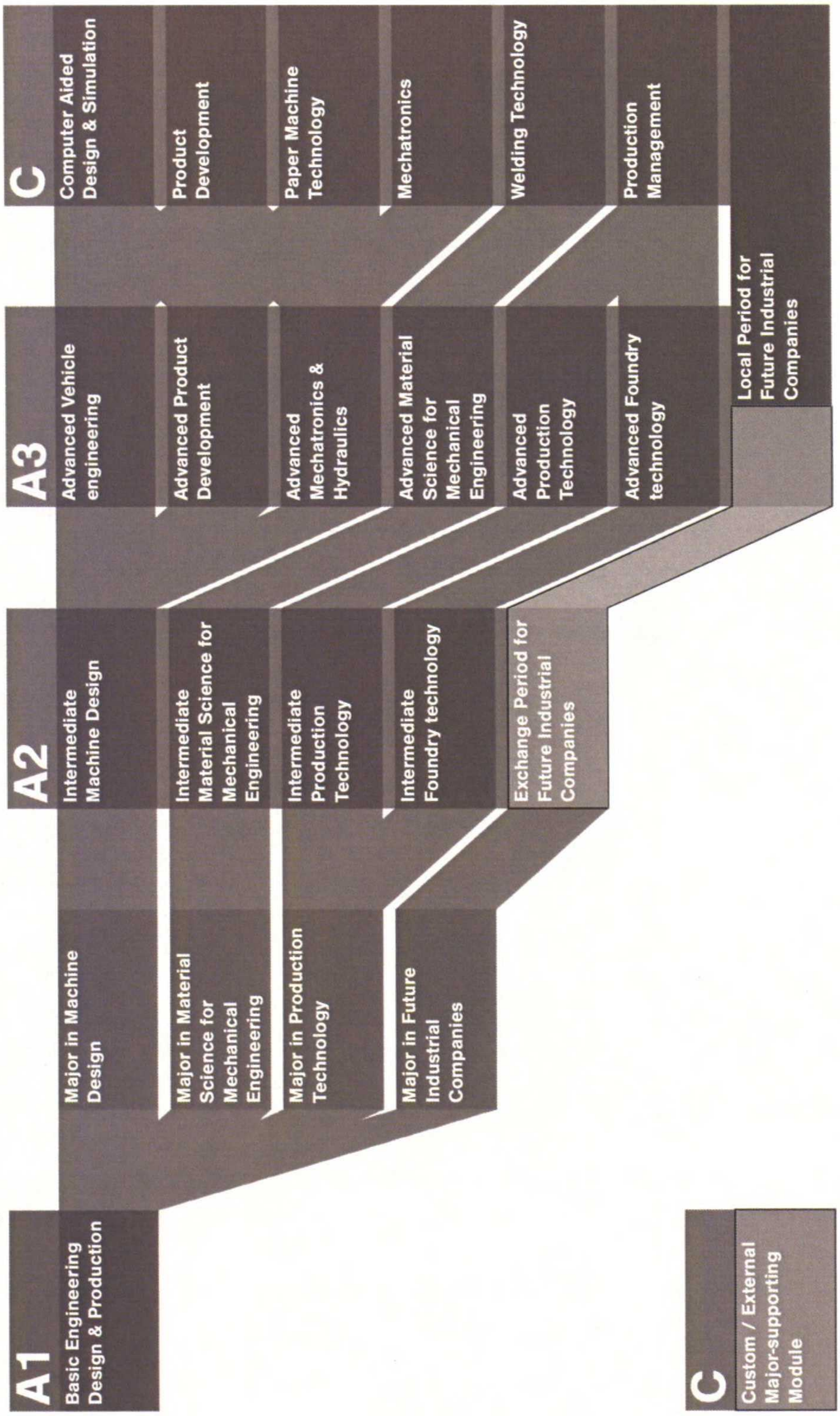

Figure 22 Modules offered by KoRa as majors (based on figures and guidelines by Jokela, et al., 2012)

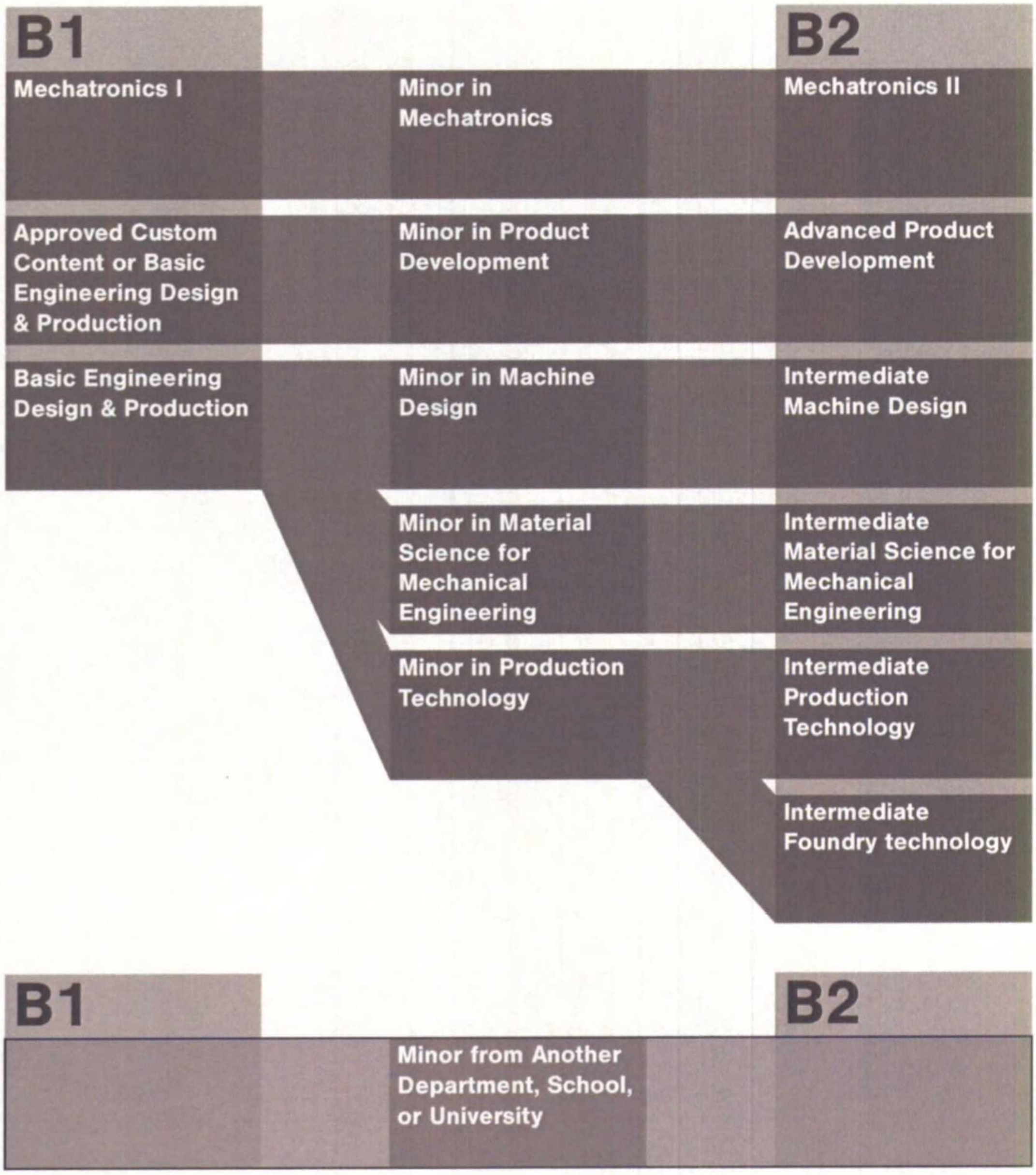

Figure 23 Modules offered by KoRa as minors (based on figures and guidelines by Jokela, et al., 2012)

Currently the BSc and MSc cycles are quite interdependent. However, changes brought about by an on-going Bachelor's Degree reform are going to make the Bachelor and Master cycles truly self-standing degrees. (Kuuva, 2012)

The goals of the Bachelor's Degree reform are the following (Kuuva, 2012):

- Conformance with the Bologna process by making the Bachelor and Master cycles truly self-standing degrees
- Make the Bachelor's degree more generic, reduce the number of majors in the bachelor stage, and eliminate narrow[10] degrees
- Improve mobility: enable exchange within the university, and facilitate fluid two-way exchange with other universities
- Make the studies more fluent and reduce the duration of degree completion; the aim is to achieve completion times that match the ideal of the 3 year BSc degree + the 2 year MSc
- Assessing and regulating the workload of courses to support the previous point
- Implementation of student- and learning-centred teaching methods
- Improve the flexibility of studies while increasing the students' responsibility over their studies
- Update the degree and teaching content to offer learning outcomes that are more relevant in the future

There will be a few big changes. First, majors in the BSc phase are planned to be reduced to three majors within Aalto ENG (Kuuva, 2012). As Figure 24 shows, there are a lot of alternative major tracks at Aalto ENG. It should be noted though, that the number major tracks are going to be simplified in the BSc programme, and freedom of choice will be maintained by increasing the quota for elective studies (Kuuva, 2012).

The planned majors for Aalto ENG are: The Built Environment, Energy and Natural Resources, and Mechanical and Structural Engineering (Kuuva, 2012). KoRa will be repositioned into Mechanical and Structural Engineering. Figure 25 illustrated the merger of the programmes into majors.

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[10] Narrow degrees are highly specified and inflexible degrees

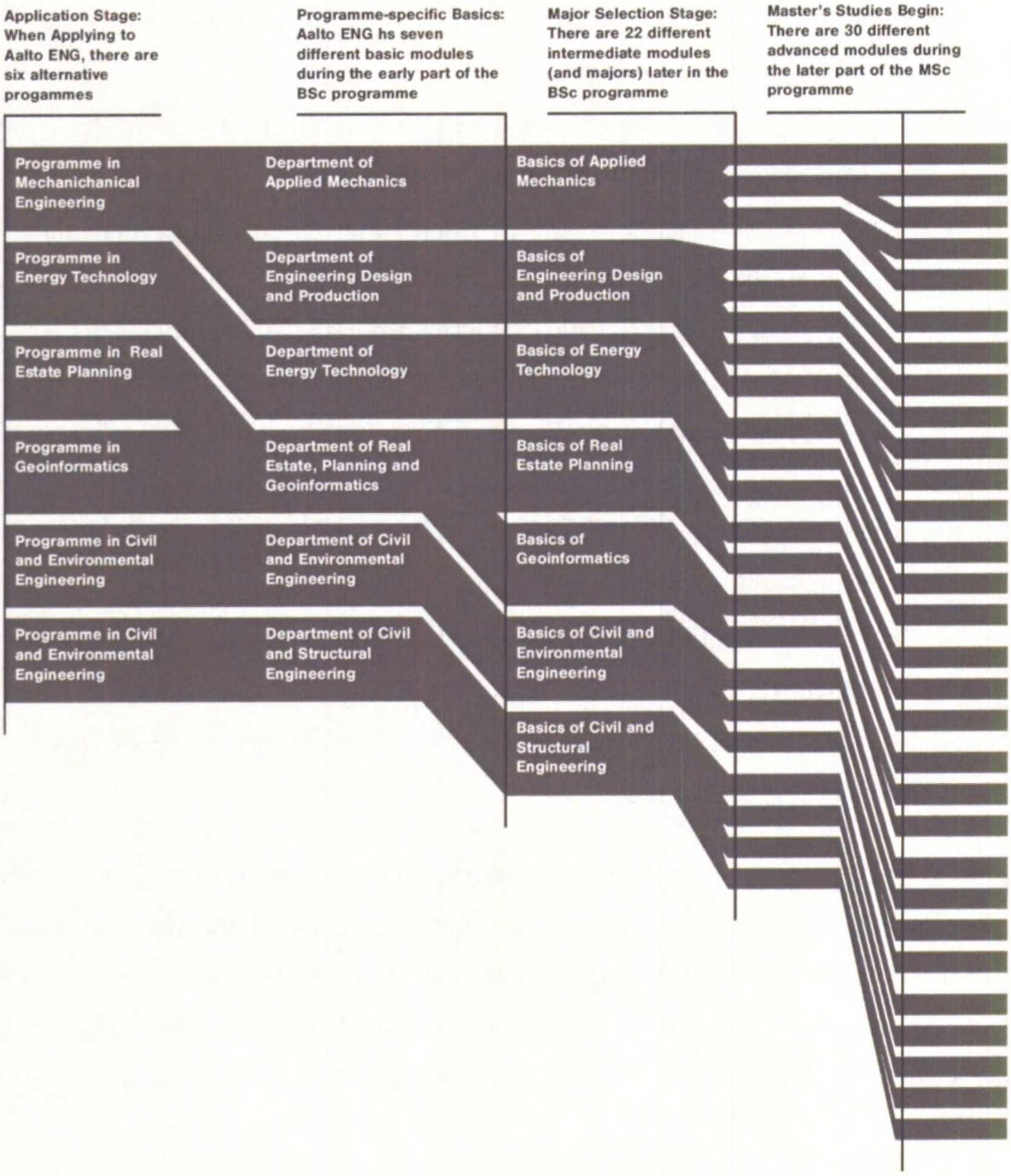

Figure 24 Current major branches in Aalto ENG and the stages of major track selection. Based on information from Into (Aalto University, Into, 2012)

The merger of the programmes will impact the selection of majors and other studies (Lemmetyinen, 2012). The stages described in Figure 24 will be impacted. The impact summarised in Figure 26. The figure is based on material by Lemmetyinen, 2012, and Kuuva, 2012.

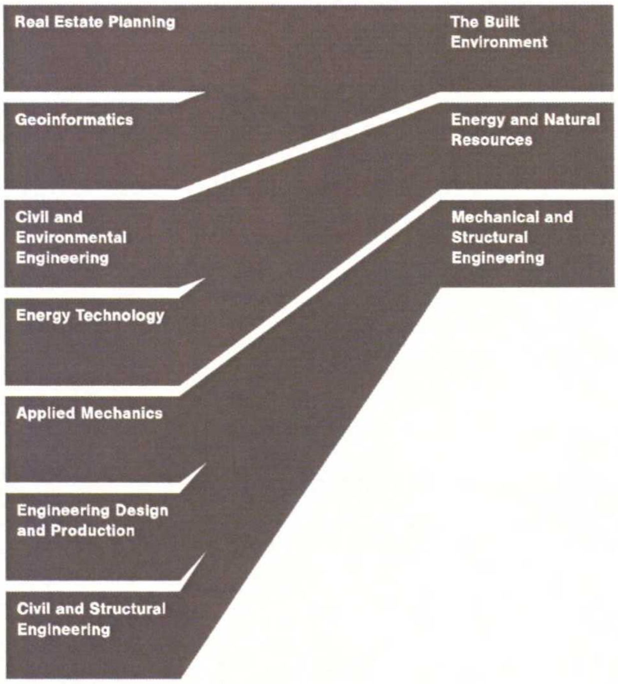

Figure 25 The merger of programmes into three majors at Aalto ENG

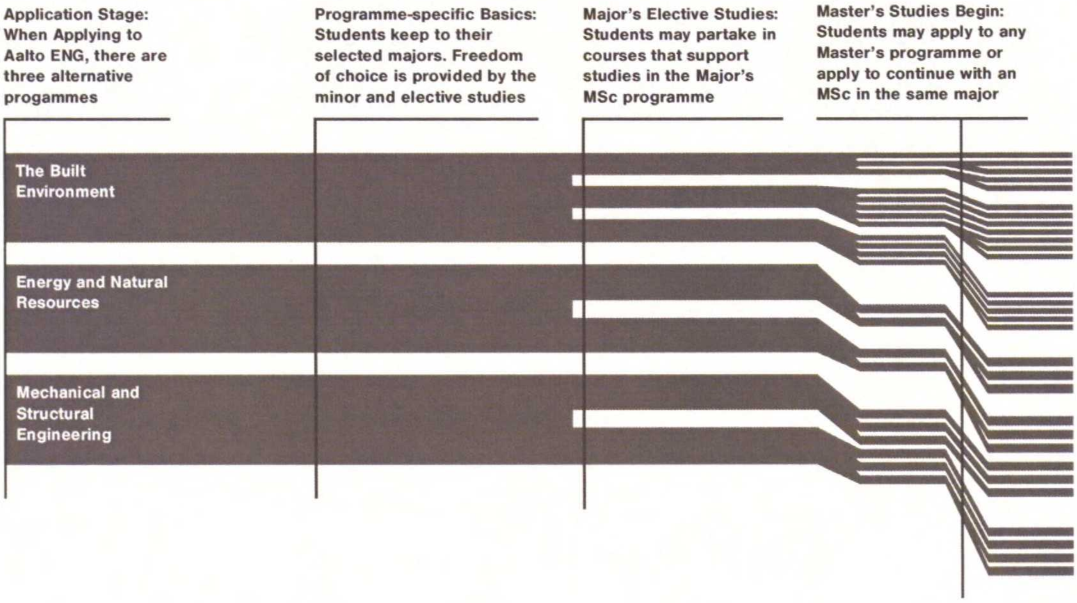

Figure 26 Revision of Figure 24 to summarise the effect of changes based on planned reform of the majors

Minors offered at the Aalto ENG will include Engineering Simulation and Design, and Civil Engineerng in addition to the minors based on the three offered majors. That adds up to five alternative minor tracks. Majors at Aalto ENG are limited to the three that are offered. (Kuuva, 2012)

All majors within Aalto ENG will be based on the same structure, which will not be based on the previously explained modular structure (Kuuva, 2012). The planned BSc and MSc degree structure is depicted in Figure 27.

Minor (25cr) may be deepened to the level of a major with the Elective Studies (25cr), which may be used to accommodate credits from exchange studies, or to accommodate unplanned perquisites. More elective, referred to as Major's Partially Elective Studies (5+5cr), have been positioned into the 60cr of BSc major studies in order to allow student to prepare for continuing with the same major in the MSc programme. (Kuuva, 2012)

The details of the BSc, degree are described in Figure 28. Positioning of the content is speculator. The details of the MSc programme are likely to be similar to the currently offered content. The MSc programme will include Elective Studies (25-30cr), a Master's Thesis Work (30cr), and advanced Major Studies (40cr). As mentioned earlier, the MSc major studies may build on studies selected by the student in the Major's Partially Elective Studies (5+5cr) part of their BSc programme's major. (Lemmetyinen, 2012)

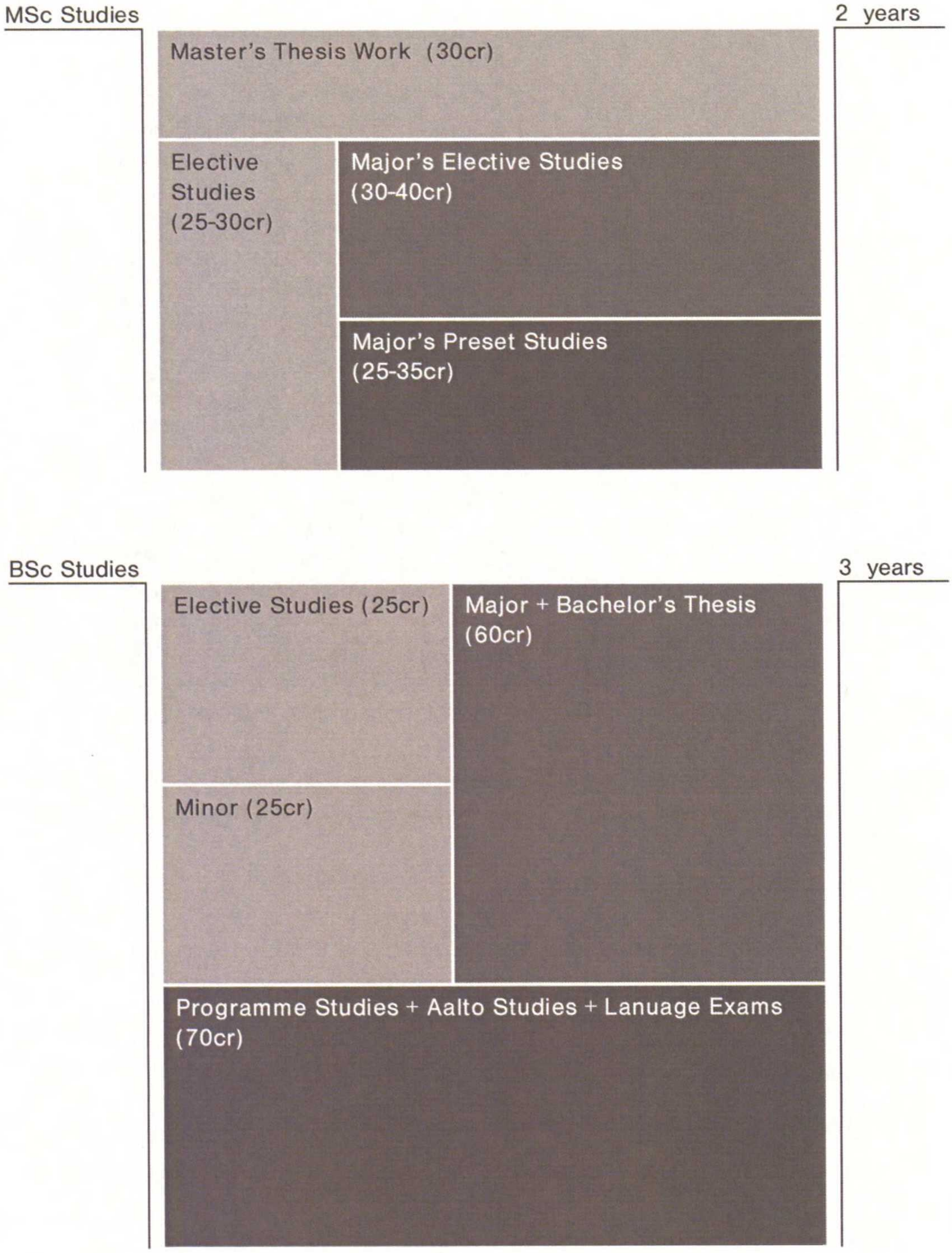

Figure 27 The planned structure of degree programmes for the autumn of 2013

In the BSc programme, Programme Studies (70cr) will be the same for all three majors. The Major (60cr) includes the Bachelor Thesis & Seminar (10cr), and the

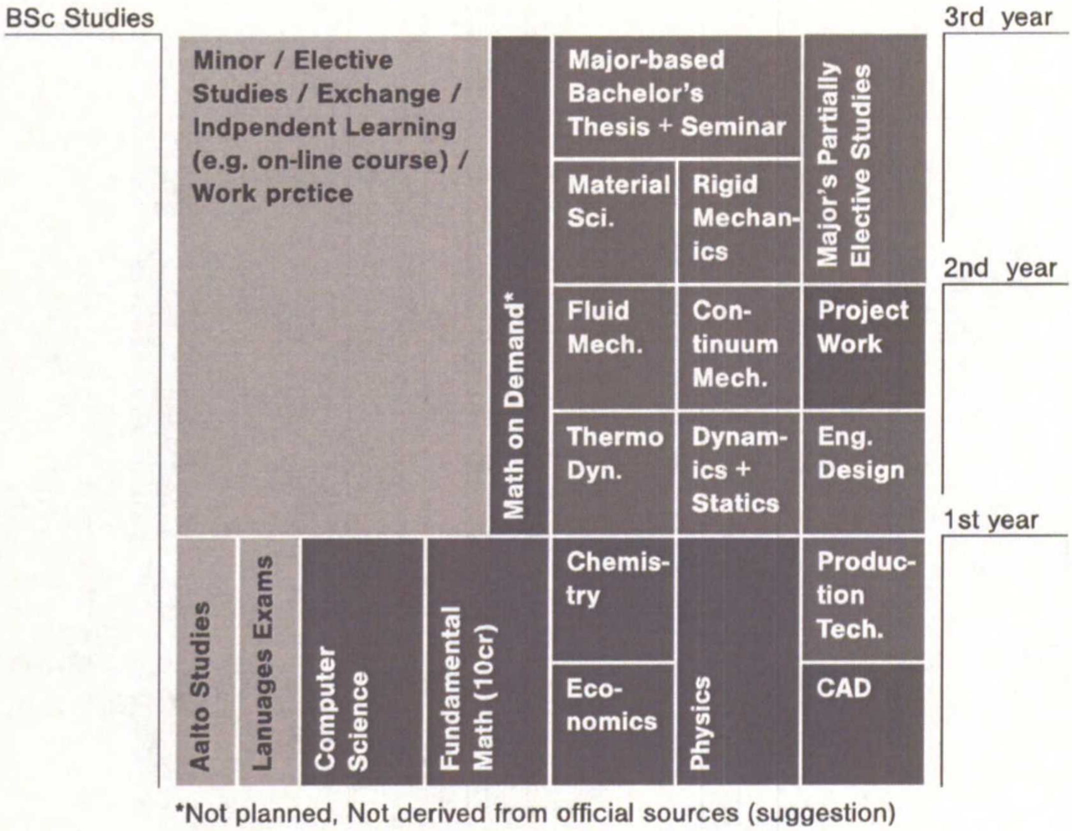

Figure 28 The planned content of the BSc programme (based on Kuuva, 2012, Romanoff, 2012, Lemmetyinen, 2012). The positioning of the courses is speculatory (especially *Math on Demand*)

3.3 Teaching and Learning

Adopting a best practice should improve teaching and learning. According to Fry, et al., (2003), teaching and learning could improve significantly if:

- students are acknowledged as resources for improving teaching and learning
- teachers could be more aware of the students' starting points
- assessment would be included into the teaching and learning process instead of being a separate tool for measuring performance
- content would be stripped down to the bare essentials

Teaching and learning today still leans heavily on very traditional methods of teacher-centric didactic teaching, which doesn't take into account the possibility of students being contributors to the teaching. Over time, it has become evident that learners bring experience into the classroom. They have differing experiences of the same teaching; they may be more motivated when offered choice, and when engaging in a new discipline, they may have difficulties thinking in the appropriate manner. In effect, teachers should reduce the amount of didactic teaching and welcome interaction and independent learning. (Fry, et al., 2003)

Teachers need to be aware of the learner's starting point to correct misconceptions and fill in gaps of knowledge, and to be aware of cultures impact to learning behaviour, interpretation, and understanding. Also, prior knowledge needs to be activated in order to ensure continuum and access long-term memory. To facilitate making of meaning, learning is at its best within relevant context. (Fry, et al., 2003)

Feedback and discussion is important for checking that individual learners are capable of accommodating new understanding. Furthermore, assessment has a powerful impact on student behaviour. (Fry, et al., 2003) Not only does assessment improve learning by allowing reflection and correction, assessment results are also extremely valuable for programme evaluation and development since they help answer questions such as *"How do we know that the students are achieving intended learning outcomes?"* or *"How do we know that our programme is efficient?"* (Crawley, et al., 2007) Assessment also helps improve the pleasantness of the learning environment. The learning climate or environment, which comprises of motivation, interaction, support, and so forth, also has an effect on the learning outcomes (Fry, et al., 2003).

Information overload can be considered one of the worst enemies of deep learning. Teachers should avoid content overload since too much information will inhibit deep learning. As mentioned earlier, didactic teaching should be reduced. Since didactic learning is, in essence, about information transfer, reducing the amount of didactic learning will also reduce the amount of information being transferred. As a result, content can be stripped down to the bare essentials - the fundamentals that provide the basis for further learning. (Fry, et al., 2003)

Essentially, learners can be divides into two groups according to their approach and motivation when it comes to learning: academic and non-academic students. By applying active teaching, the gap the two student groups decreases from A to B in Figure 29. (Hyppönen, et al., 2009)

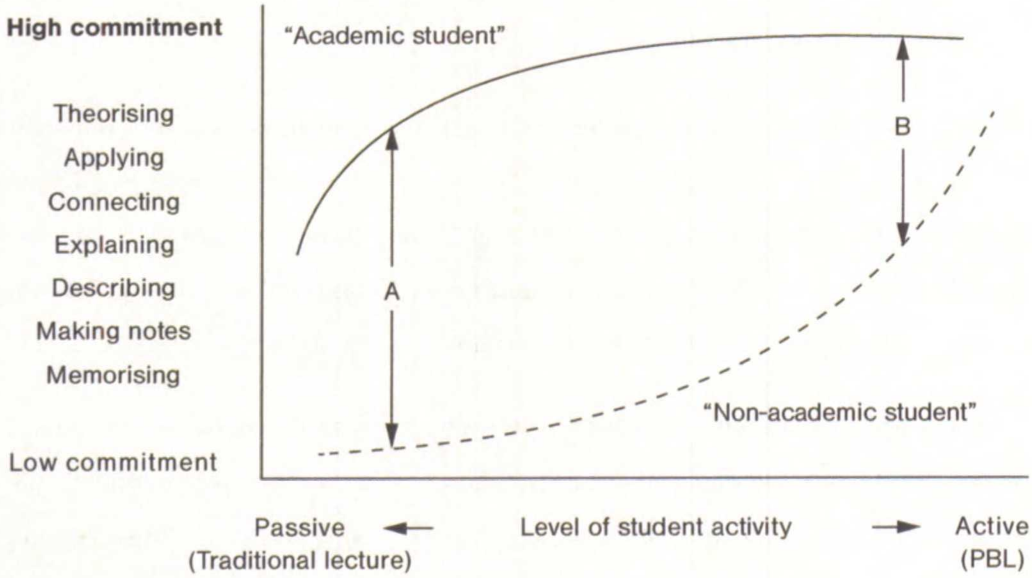

Figure 29 Correlation between teaching methods and student commitment (based on adaptation by Hyppönen, et al., 2009)

When it comes to education, students have different backgrounds and they also have differing expectations. Furthermore educators have very different approaches to teaching and learning. This spread has resulted in publications, which represent different schools of thought about how learning takes place. One of the most notable schools of thought is constructivism. (Fry, et al., 2003)

3.3.1 Constructivism and the Spiral Curriculum

An understanding of thought processes is vital when looking to improve teaching and learning. In this work, constructivism is adopted as the guiding school of thought when dealing with theories on teaching and learning.

In constructivism, learning is a process of individual transformation i.e. individuals actively construct their knowledge and learn by fitting new understanding in reference and relevance to old knowledge and understanding. Experiential learning and the use of reflection, for instance, are current ideas that are based on constructivism. Any learning of higher order, for instance, learning that involves understanding or creativity, may often require the learner to change in order to incorporate new understanding. Therefore, learning can be improved by inducting students into modes of thinking, and giving them the possibility to revise knowledge at ever-higher levels. (Fry, et al., 2003)

Table 2, below, is an example of how the spiral curriculum presented in Figure 30 can be applied for mechanical engineering education.

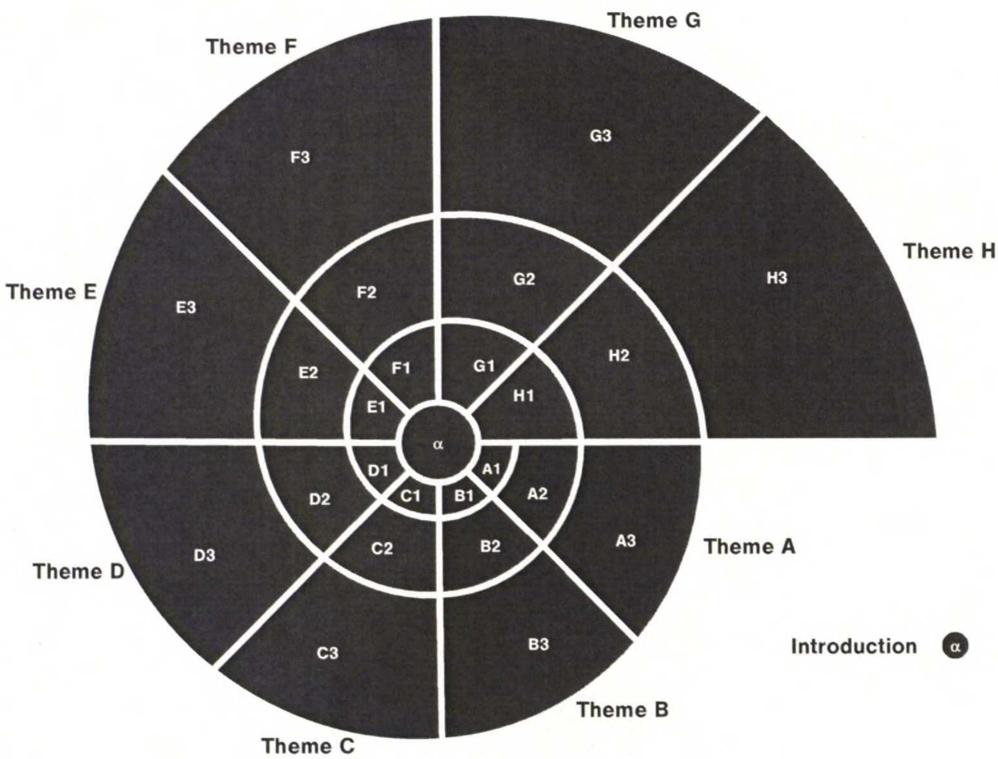

Figure 30 Spiral curriculum redrawn based on Neary's model (Neary, 2002)

Table 2 Example content for a spiral curriculum in mechanical engineering education

Programme Stages → Themes ↓	1: Introductory studies	2: Bachelor's Studies	3: Master's Studies
A: Mathematics & Physics	A1: applying math & physics in engineering	A2: math & physics for current studies or projects	A3: math & physics for current studies or projects
B: Computer Aided Design, Engineering, & Manufacturing	B1: CAD & technical drawing fundamentals	B2: CAD/CAM/CAE for product development, prototyping, & production	B3: Advanced applications for CAD/CAM/CAE in projects
C: General Engineering Skills & Optional Studies	C1: basic studies in programming, electronics, chemistry, biotech, & nanotech	C2: optional studies in programming, electronics, chemistry, biotech, & nanotech	C3: optional studies in programming, electronics, chemistry, biotech, & nanotech
D: General Organisational Skills & Optional Studies	D1: basic studies in design processes, industrial economics, leadership, & work psychology	D2: optional studies in design processes, industrial economics, leadership, & work psychology	D3: optional studies in design processes, industrial economics, leadership, & work psychology
E: Work Placement & Optional Studies	E1: Work environment training or optional studies	E2: professional training or optional studies	E3: professional training or optional studies
F: Minor Studies	F1: Minor Studies	F2: Minor Studies	F3: Minor Studies
G: Major Studies	G1: Major Studies	G2: Major Studies	G3: Major Studies
H: Scientific Seminars	H1: seminar on scientific research, documentation, & publication	H2: Bachelor's Thesis seminar	H3: Master's Thesis Seminar

In the example presented in Table 2, a spiral curriculum in mechanical engineering can start from an introductory course (α), which introduces the context of mechanical engineering very broadly with highlights and examples of professions in mechanical engineering. All the themes are present in all the stages of the programme. The idea is of the themes being present throughout the studies is that the students constantly build on previous knowledge. The degree programme starts from the middle and spirals outward. Project work, performance training, languages, engineering ethics, and other courses focusing distinctively on interpersonal skills are not mapped out in this example of the spiral curriculum because, according to CDIO standards, they should be an integral part of engineering courses (Crawley, et al., 2007).

There are alternative schools of thought, such as rationalism, which is considered to be the alternative pole to constructivism, and associationism. The fundamental idea of rationalism is the existence of a biological plan which unfolds in a defined order. (Fry, et al., 2003)

3.3.2 Learning outcomes: Education Taxonomies of SOLO and Bloom

The Structure of the Observed Learning Outcome (SOLO) taxonomy and Bloom's taxonomy are guidelines for defining intended learning outcomes (ILOs), and learning assessment. Table 3 lists verbs that students have to enact to work towards ILOs. The SOLO taxonomy and the 2001 revision of Bloom's taxonomy are complementary of one another with a few exceptions. Both taxonomies are also models for describing levels of increasing complexity in learning.

The general student is driven by assessment. They generally optimise their performance for getting the best possible assessment results, rather than best possible attainment of ILOs. Assessment should be implemented so that better attainment of ILOs results in better assessment results; i.e. focus of assessment should be placed on learning outcomes and how to help students achieve them. Aligning assessment and ILOs in such a way is known as constructively alignment. (Biggs, et al., 2007)

Table 3 verbs for ILOs in the SOLO taxonomy and Bloom's taxonomy adapted from Biggs, et al., (2007)

Some verbs for ILOs from the SOLO taxonomy	
Unistructural	Memorize, identify, recognize, count, define, draw, find, label, match, name, quote, recall, recite, order, tell, write, imitate
Multistructural	Classify, describe, list, report, discuss, illustrate, select, narrate, compute, sequence, outline, separate
Relational	Apply, integrate, analyse, explain, predict, conclude, summarize (précis), review, argue, transfer, make a plan, characterize, compare, contrast, differentiate, organize, debate, make a case, construct, review and rewrite, examine, translate, paraphrase, solve a problem
Extended abstract	Theorize, hypothesize, generalize, reflect, generate, create, compose, invent, originate, prove from first principles, make an original case, solve from first principles

Some ILO verbs from Bloom's revised taxonomy	
Remembering	Define, describe, draw, find, identify, label, list, match, name, quote, recall, recite, tell, write
Understanding	Classify, compare, exemplify, conclude, demonstrate, discuss, explain, identify, illustrate, interpret, paraphrase, predict, report
Applying	Apply, change, choose, compute, dramatize, implement, interview, prepare, produce, role play, select, show, transfer, use
Analysing	Analyse, characterize, classify, compare, contrast, debate, deconstruct, deduce, differentiate, discriminate, distinguish, examine, organize, outline, relate, research, separate, structure
Evaluating	Appraise, argue, assess, choose, conclude, critique, decide, evaluate, judge, justify, predict, prioritize, prove, rank, rate, select, monitor
Creating	Construct, design, develop, generate, hypothesise, invent, plan, produce, compose, create, make, perform, plan, produce

According to Biggs, et al., (2007), there are four steps to designing constructively aligned teaching:

1. Describe intended outcomes in the form of standards students are to attain using appropriate taxonomies (learning verbs)
2. Create a learning environment likely to bring about the intended outcomes
3. Use assessment tasks enabling you to judge if and how well students' performances meet the outcomes
4. Develop grading criteria (rubrics) for judging the quality of student performance

Intended Learning Outcomes at KoRa

The intended learning outcomes listed in KoRa's study guide can be divided into five categories: professional competence, scientific competence, continuous personal development and learning, interpersonal skills, and ethics. In general the students graduating from mechanical engineering are supposed to be capable of both theoretically demanding work, and practical work of a Master of Science in Engineering (Jokela, et al., 2012). The following learning outcomes, based on the objectives stated by Jokela, et al., 2012, are placed into the five categories mentioned:

Professional Competence:

- A deep level of expertise in the field of mechanical engineering
- Capability to complete demanding tasks for experts and produce results
- Capability for new and creative work that combines different disciplines and may operate in an international surrounding
- Capability to perform high-quality and professional work
- Diverse IT skills
- Ability to function as experts or leaders in design, production, research, product development, or technical procurement and maintenance

Scientific Competence:

- Strong competence in the fundamentals of mathematics, science, and mechanical engineering
- Capability to conduct research, and create advancements in the field
- Capability to engage in scientific thinking and work and generate scientific knowledge
- Motivate students to comprehend the scientific significance and opportunities in studying, teaching, and research
- Capability for new and creative research that combines different disciplines and may operate in an international surrounding
- Eligibility for different kinds of teaching professions

Continuous Personal Development and Learning:

- Capability to learn continuously
- Capability to acquire scientific knowledge independently and apply it in work or for the good of advancing engineering sciences
- Capability to broaden personal area of competence or to redirect the activity of the work community

Interpersonal Skills:

- Clear written and spoken communication skills
- Good language skills
- Good team working skills
- Competence in leadership and project activity, and economic knowledge

Ethics:

- Awareness of environmental problems and ways for solving them
- Readiness to solve national and international mechanical engineering challenges

These points add up to a great plan. However, the implementation of some of these learning outcomes needs to be worked on (Aaltonen, et al., 2011).

3.3.3 General Practices in Teaching and Learning

There are many tools for teaching and learning. Learning can be passive or active. People can learn independently or in groups, with or without and instructor. There are various teaching methods that work better for some learning situations than others and better for certain topics than others. Passive learning is teacher-centric learning, where students absorb information with little or no interaction. Active learning is student-centric learning, where students have to act or interact in order to expose information. Passive learning is associated with didactic teaching; active learning is associated with participative teaching. (Fry, et al., 2003)

Out of all the tools, lecturing, which is a didactic form of teaching, remains common in university education even though writing in the 1980s predicted the demise of the lecture. The use of lectures should not, and will not disappear. Lecturing, as a method of teaching has evolved with the introduction of PowerPoint and, recently, with recording, virtual distribution and live streaming. (Fry, et al., 2003)

Blended Learning is the mixture of e-learning and contact teaching[11]. In blended learning it is very important that teaching and learning is about more than the quality of the content. Interaction is a very important component in blended learning; interactive teaching takes into account how students work alone or in groups, how teachers moderate activities and curate sources and learning technologies, how assessment engages students and supports learning, and how well media and other available tools are used to instruct and inspire students. (Fry, et al., 2003)

3.3.4 Problem-based Learning

Looking at engineering universities and polytechnics, in 1997 the ratio of teachers to students was 1:10. Fast forward to 2009 and the ratio had shifted to 1:22 (Korhonen-

[11] Lecturing, guided classroom teaching and such

Yrjänheikki, 2011). There has gradually been a move towards teacher centric mass lectures with growing numbers of participants. Nonetheless, small group methods have been retained and enhanced in higher education because of the need to insure quality of the learning experience, deliver key skills, and create potential for innovation. (Fry, et al., 2003)

Problem-based learning has been around since the 1960s (Fry, et al., 2003). The core of PBL is the belief that contextual, student-centric, and active learning is the most effective and stimulating way to learn. PBL has been a natural solution in education since professional training began to transfer into educational institutions. Consequently, reforming engineering education towards the context of real-world demands, and PBL are necessary for aligning engineering education with the career paths of engineering graduates (Crawley, et al., 2007). (Boud, et al., 1991)

PBL is needed for deepened learning, and for integrated learning, which develops human and professional skills that are required in the workplace environment. In turn, deepened learning is necessary for grasping the fundamentals. The creation of the ideal PBL learning environment in an educational institute is rather challenging for two main reasons: (Crawley, et al., 2007)

- the educational institute needs to provide the ideal facilities and tools for PBL
- unless university policies change drastically, students still need to be graded according to set standards even though evaluation is complicated for PBL

To create the ideal learning environment, it is important to train staff and students, provide adequate working spaces, and ensure that the required resources are available. (Fry, et al., 2003)

3.3.5 Assessment as a Tool for Teaching and Learning

It has been pointed out that teaching could be improved significantly if assessment would be included into the teaching and learning process instead of being a separate tool for measuring performance (Fry, et al., 2003). One way of doing so is to plan teaching and assessment should so that they support ILOs (Biggs, et al., 2007).

PBL, like other approaches to teaching, requires assessment methods that are relevant to the expected learning outcomes, and provide appropriate means for evaluation (Fry, et al., 2003). Many measures used to assess the proficiency of students are inaccurate and inadequate for giving a reliable prediction on how students will perform in real world challenges. In general, exams do not measure how community-orientated a student is, or how well they continue to develop as a self-directing learner. This makes the finding of good measures for assessment especially challenging for PBL. (Boud, et al., 1991) According to Fry, et al., (2003), the need for unique assesment methods in PBL is supported by the following points:

- PBL students take more of a deep approach to learning
- Students on a traditional curricula tend to score slightly higher on conventional tests of knowledge, but PBL students retain their knowledge longer
- Students perceive PBL as more clinically relevant and rate their programmes more positively

Teaching and learning can improve significantly when students are acknowledged as resources for improving teaching and learning (Fry, et al., 2003). This applies for assessment when self- and peer-grading are used (Sadler, et al., 2006).

Assessment, especially assessment of PBL-like open ended exercises, is commonly a time- and resource-consuming process for teachers. At the same time, students are tend to receive the final verdict without being actively involved in the grading process, which could be reflection and retrieval practice. Peer- and self-grading are effective as time savers for teachers and as learning enhancing exercises for students. It should be noted that studies show that self-grading increases student learning while peer-grading does not. (Sadler, et al., 2006)

According to Sadler, et al., (2006), self- and peer-grading offers four potential advantages over teacher grading:

- **Logistical:** simultaneous grading in short amounts of time, quick feedback, more detailed feedback
- **Pedagogical:** evaluating answers is an opportunity for students to deepen their understanding, and being exposed to other student's point of view may give birth to new ideas of further develop skills
- **Metacognitive:** assessment as a part of student learning can induce learning beyond the specific content, and demystify testing. It can help students develop a proactive attitude towards evaluating their own work while developing as evaluators of their peers' work, and create better awareness of strengths, progress and gaps. Furthermore, self-evaluation and peer review are an important part of future, adult, professional practice.
- **Affective:** student involvement in grading produces a more productive, friendly and cooperative atmosphere, as well as a greater sense of ownership for the learning process.

Self- and peer-grading has its limitations. It can be considered a valid substitute for teacher grading only when the results of the grading practices are comparable to the teacher's grading practices. These limitations are easily measured for straight forward multiple-choice or fill-in-the-blank exercises, but comparability becomes difficult when open-ended or creative exercises are assessed. Consequently, self- and peer-grading of opened-ended exercises is something that students need to learn (Sadler, et al., 2006)

Figure 31 shows how student grading and teacher grading can be really well correlated. This proves that there are cases where student grading can substitute teacher grading. (Sadler, et al., 2006)

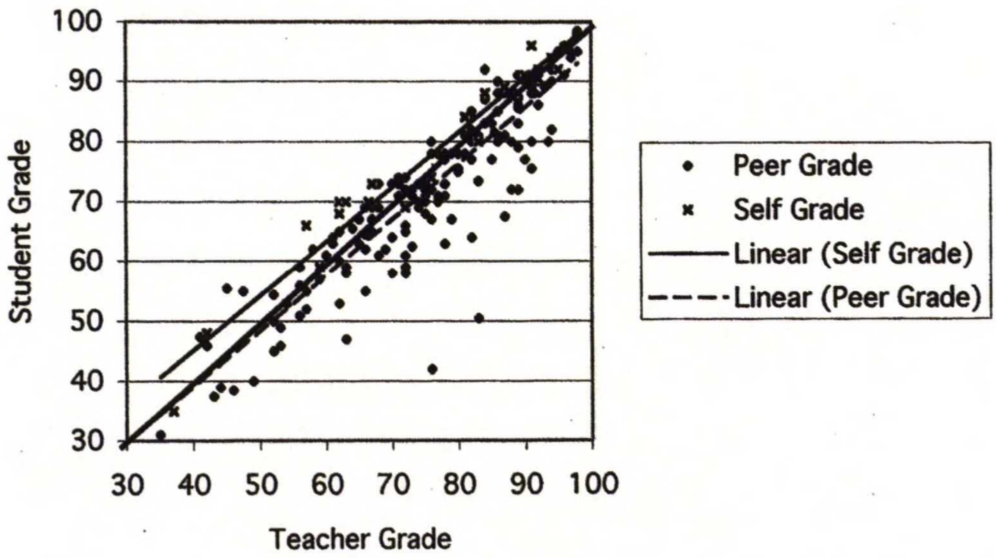

Figure 31 Comparison of teacher grade with peer- and self-grades and best-fit lines (Sadler, et al., 2006)

3.4 Synopsis of Literature Review: Defining Best Practice

The context of mechanical engineering education in Aalto is defined by applying the context of engineering education from the CDIO Initiative, and by using the Aalto strategy to specify the definition to Aalto. One of the assumptions in this study is that best practices are practices that are aligned with the Aalto strategy, suggested by the CDIO Initiative, and seconded by theories on teaching and learning. Figure 32 illustrates how the definition for best practice is derives by filtering teaching-related practices and philosophies through educational theories, the Aalto strategy, and the CDIO standards.

Teaching theory highlights constructivism as a ground theory for teaching and learning. To recall the keys to improving quality of learning: students should be acknowledged as resources for improving teaching and learning, teachers should be more aware of the students' starting points, assessment should be included into the teaching and learning process instead of being a separate tool for measuring performance, and content should be stripped down to the bare essentials. (Fry, et al., 2003)

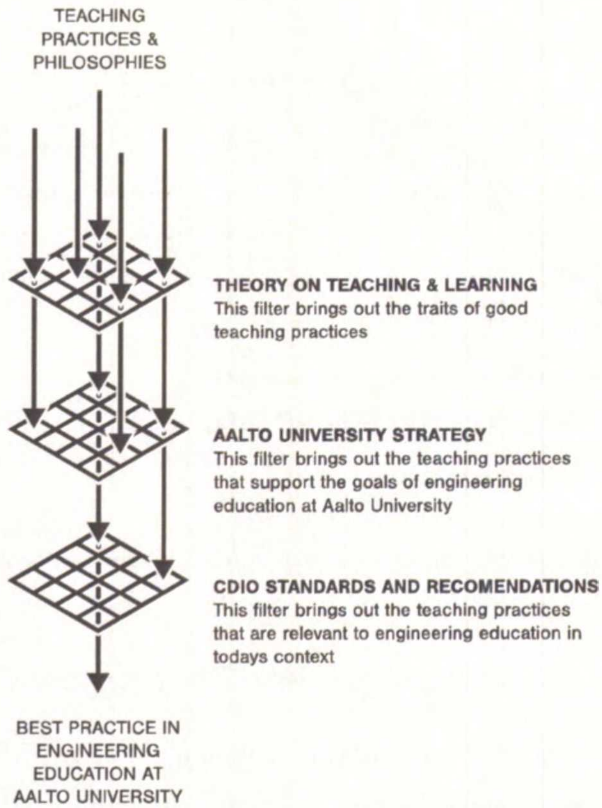

Figure 32 Filtration of the definition for Best Practice

The key points that this study can take from teaching and learning theory are:

- Learning is most effective when knowledge is acquired constructively, i.e. by building on previous knowledge (Fry, et al., 2003)
- People have different habits of learning, therefore, an institution that has a variety of alternative learning methods in use, is likely to be efficient in teaching (Fry, et al., 2003)
- Teaching and assessment should actively involve students, with the purpose of creating a sense of ownership for the learning process, speeding up feedback times, deepening learning, and developing the skills of self-evaluation and peer review (Sadler, et al., 2006)

- Assessment is a critical part of education and should be included in the teaching and learning process (Crawley, et al., 2007) (Fry, et al., 2003) (Biggs, et al., 2007)
- Learning outcomes need to be designed to be clear. They should describe the level and approach to learning: in what way a student should be able to show the knowledge/skills acquired and the level at which the knowledge/skill should be acquired (Crawley, et al., 2007)

The Aalto strategy defines that the direction of teaching and learning is towards practices that produce and apply knowledge with the goal of creating a better world (Aalto University Strategy, 2011). The CDIO standards help to specify specific traits of best practice in engineering education, how to apply them, and how to continue to develop them (Crawley, et al., 2007). The principles of CDIO address two central questions:

- What knowledge, skills and attitudes should students possess as they graduate from university?
- How can we ensure that students learn these skills?

To address these questions, representatives of the industry, government and universities developed lists of desired attributes of engineers (Figure 10 on page 25). Some key attributes within the list were: understanding of fundamentals, understanding of design and manufacturing processes, a multidisciplinary perspective, good communication skills, and high ethical standards. The creation of these lists brought up the deficiencies within the current state of engineering education in general, which can be summarised as too theoretical and not practical enough. As mentioned in the introduction, engineering programmes have been shifting emphasis form a practice-based curriculum to a science-based curriculum. The deficiencies identified translate into a need to educating students who understand how to conceive, design, implement and operate complex, value-added systems in a modern, team-based environment. (Crawley, et al., 2007)

The literature review is used as a basis for defining best practice and to answer the first research question (**What are best practices and how are they relevant to KoRa?**), the definition of best practice can be formed.

Best Practice (in the context of this study): A practice that promotes learning-centred education where learning is based on constructivism, learners and teachers produce new knowledge and come to understand how to apply their knowledge for the benefit of society. Even though best practices commonly work well, their weakness is their relevance in the changing world. Therefore, they need constant re-evaluation.

4 Data Collection and Analysis: The Search

This section brings together the observations and extractions from relevant sources. The two methods of data collection are case studies and PAR. Case study data is derived from the TEE reports, and a brief summary of my personal experiences as a student and faculty member of KoRa. The following subsection is a review of the results from the workshop.

4.1 Workshop Summary: Perspectives on Education Reform

The planning and organisation of the workshop is explained in Section 2.4.2 along with the methods used in this study. A total of 14 attendants were at the workshop. Representation by stakeholder groups:

- Professors, teaching faculty, educational planner, and department management (10 attendants)[12]
- Three members of the CDIO community (Tampere Technical University)
- Two students (one with an entrepreneurial background, the other a faculty member as well as a student and entrepreneur)
- Industry partners (none attended)

The responses from each of the workshop groups are collected and summarised. The nine small groups discussing over three periods produced valuable results.

4.1.1 Part 1: Past, Present and Future

What was well? How are things now? Where will the future of engineering education be like?

[12] One of the attendants is a faculty member and a student

Group 1 - Past: What was being done well? When looking at the past of history of KoRa, one of the workshop groups list items on a poster, which identified the strength of KoRa to be:

- The collaboration with the industry for Master's Thesis work
- Laboratory exercises
- Teachers having industrial experience
- Students having the ability to work independently
- Education for employment
- The ability to make decisions
- Practicality
- Sabbatical years in the industry

This pallet of strengths shows that collaboration with the industry, blended learning through practical work, and a sense of flexibility are elements that have been working well at KoRa. There is a strong indication that the CDIO goal, of educating engineers who can engineer, is well in line with KoRa's past educational activity. Notes from the individuals in the entire workshop suggest that the on-going change process is good and needs to continue, and that some of the faculty is relatively satisfied with the existing co-creation spaces.

Group 2 - Present: What is the current state of KoRa? Figure 33 is a reconstruction of the poster produced by this group during the discussions.

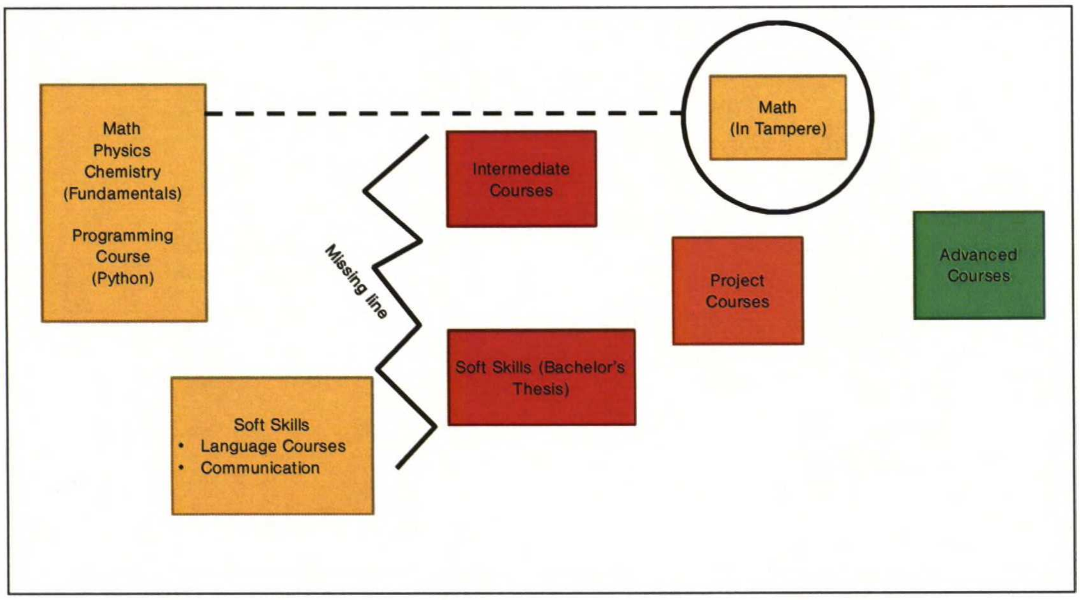

Figure 33 Reconstruction of the poster from Part 1, Group 2 of the workshop

From the figure, it can be seen that the group recognises an existing separation between soft skills (human skills) and fundamentals, intermediate courses, and advanced courses. There is an example, from Tampere Technical University, of how mathematics can be stretched out to support the later studies. The need for project courses in the curriculum is presented between the intermediate and advanced courses.

Individual comments from a participant outside of the group suggests that more creative freedom is needed in the BSc phase, while there is more freedom of creativity in the master's phase. The same individual also expresses that the learning outcomes of graduating students fulfil the requirements of the industry, due recently implemented career planning courses.

Group 3 - Future: What will be required in 2020 and how will we teach then? Table 4 is a reconstruction of the poster created by the group during their discussions.

Table 4 Reconstruction of poster from Part 1, Group 3 of the workshop

- Motivation
- Reading books and study material in depth
- What is the practical interest of some basic courses
- Input/output ratio is bad
- Dealing with uncertainty and decision making, crisis management
- Routine
- Holistic viewpoint
- Find info., select the info., evaluation
- Being able to deal with pressure
- Communication skills
	Actions
	
	- Less students, projects, co-creation
	- More coaching feedback
	- More flexibility
	    - Must know
	    - Should know
	    - Nice to know
	- What is mandatory/optional
	- Projects
	- Training by coach, feedback
	- Better connected to research and industry specialists
	- Exercises
	- Projects, evaluation
	- Combined, training, feedback

The group is implying that the requirements for future graduates are motivation, deep learning, and mastery of fundamentals and the capability of applying them in the real world. Furthermore the group suggests that an improved efficiency of teaching is necessary to get the most out of students without requiring excessive effort. Risk management, routine, and a holistic view, will also be required. It is also implied that finding, curating and evaluating new knowledge, being able to work under pressure, and sharpening of communication skills will be required from engineering education.

According to the group, actions for meeting the future requirements are: the reduction of student intake, adaptation of more project work and co-creation, additional efforts in assessment to provide more coaching and feedback, and improved clarity and flexibility in the curriculum. It is implied that learning outcomes must be given status of importance so that learning outcomes can be tagged as: must know, should know, and nice to know. This can give clarity on what is actually mandatory and what is optional. The need for projects and a real-world context of education is brought up repeatedly: projects, integrated feedback, evaluation and training, as well as connections to research and industrial specialists are considered important.

The individual input from the forms is extensive for this group's topic. According to participants in the workshop, the graduating engineer of 2020 should first and foremost be motivated; there needs to be a passion for lifelong learning, and a need to learn, not only why, but how. The future engineer should also be able to seek knowledge, select appropriate sources and justify their choices without the fear of making mistakes, and have a holistic perspective and system level understanding. A student perspective argues that the fundamentals will be important for the future graduate in more breadth and less depth, and that specialisation should be done at an earlier stage (than the second year). The student perspective also reinforces that communication training is important, studying should be less exam-focused and more project-based, and support should be offered to advance the student's studies in the case of unplanned barriers to the progress of studies. Creativity, teamwork capability, and leadership are also brought up as an important element for future graduates.

When it comes to methods of teaching in 2020, hands-on and problem-based learning is a popular point among the answers of individuals. It is also suggested that students should become familiar with the content by reading before, so that they can be engaged in discussions afterword. Doing so would require initiative and curiosity from the students. That curiosity and initiative can be exercised with open-ended problems and practice in seeking, analysing and evaluating information.

4.1.2 Part 2: Integrating CDIO

Should CDIO practices be included in our courses?

Group 4 - Existing Integration of Interpersonal Skills: What interpersonal skills are already integrated into engineering courses? Figure 34 is a reconstruction of the poster produced by this group.

From the poster, it can be seen that there are many forms of human skill-building element already in place in the programme. Group work is very common practice within KoRa's programmes; working is at least bilingual, commonly trilingual and includes four or more languages in the case of many students, and presentation is integrated into the courses quite often. Written skills are a natural part of nearly all the courses. In summary, the current courses incorporate a lot of collaborative group work that trains interpersonal skills. On the downside, it is mostly mechanical engineers working with other mechanical engineers.

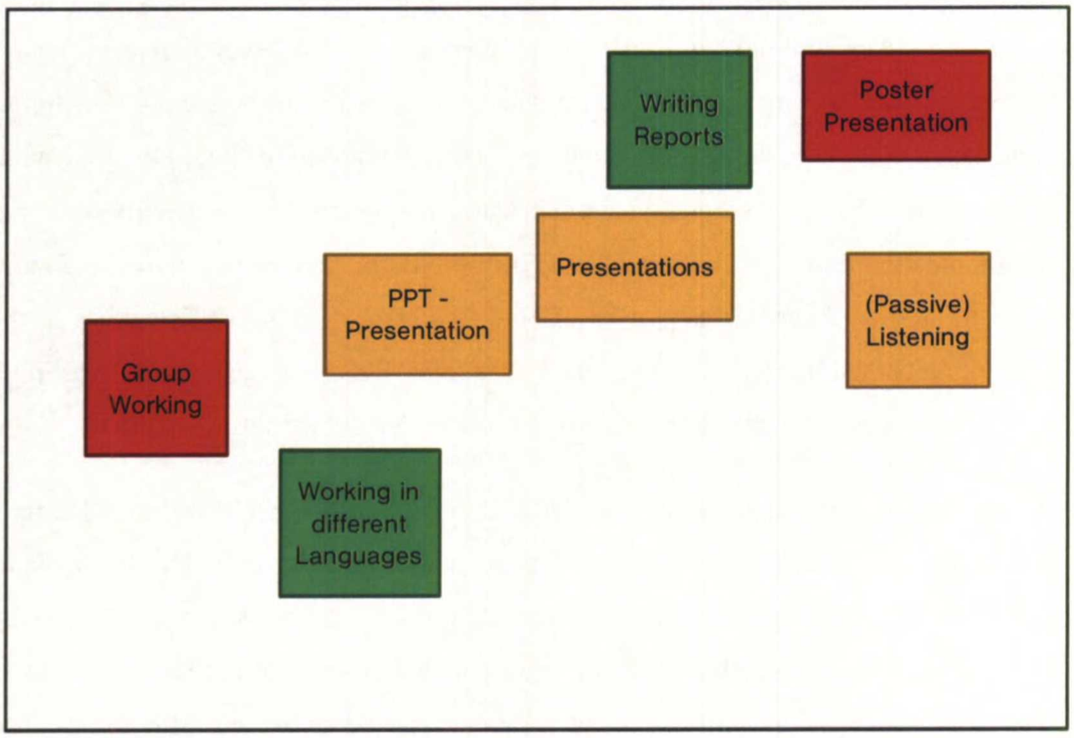

Figure 34 Recreation of poster from Part 2, Group 4 of the workshop

In the individual comments, students indicates that speech communication, working with industrial partners and subcontractors (in PDP[13]), and in-class presentations of projects are a common. Faculty indicates that the same elements are present, and add that reporting, teamwork, leadership, independent work, and meeting conduct and negotiation are also in integral part of the teaching.

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[13] PDP is the Product Development Project Course. In this course approximately 8-10 students from different disciplinary backgrounds are given a brief and a budget by an industrial sponsor, with whom they consult for the duration of the 8 month project. The students are required to deliver a functional prototype, and the relevant documentation, at the end of the course.

Group 5 - Integrating Interpersonal Skills: What interpersonal skills **can be** integrated into engineering courses? Figure 35 is a reconstruction of the poster created by this group.

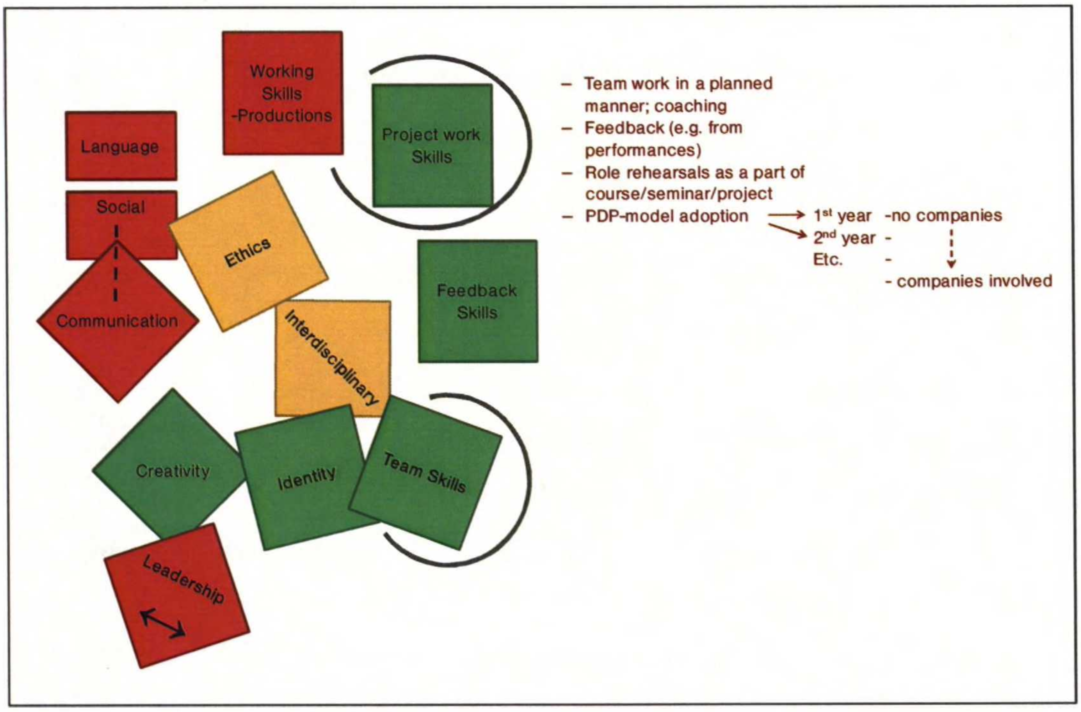

Figure 35 Recreation of poster from Part 2, Group 5 of the workshop

The group produces plenty of ideas for integration. Ethics and interdisciplinarity are placed in the centre and surrounded by project work, team skills, and personal skills such as: creativity, identity, and assessment. Interpersonal skills also surround ethics and interdisciplinarity. Team work and project work, which are highlighted, are to be included in a more planned manner, and coaching and feedback are also important. Coaching and feedback can provide assessment that supports learning by allowing reflection (Crawley, et al., 2007) (Fry, et al., 2003). Students should get the opportunity of rehearsing different professional roles as part of their courses, seminars, or projects. Design-implement experiences should be included throughout the studies, as suggested in the CDIO standards (Crawley, et al., 2007). The involvement of industrial companies in projects could be integrated progressively, as the projects become more professional in later parts of the studies.

Individual input of the participants points out that even more language and communication, social activities, creative work, leadership training, professional skills, and interdisciplinary team work skills should be integrated. Cultural understanding and ethics are also highlighted as significant necessities.

Group 6 - A Redesign of the Program Structure: Integration through project modules. The poster from this group lists the following items:

- A kick-off project and a group work
- Requires an increase in teaching staff and a radical increase of teaching spaces
- "pneumatic motor" construction
- Subcontracting of mathematics and physics
- Educational programmes resemble project work
- Vocational subject projects from the industry
  (=> is strengthened by product development/mechatronics project work)
- Projects that span the academic year
- Toss into a "cold pool" => motivation[14]

The points by the group suggest that introduction to engineering can start with a kick-off project and group work. The construction of a pneumatic motor is given as an example subject for an introductory project work. It is pointed out that intensified project work will require radical increases in teaching staff, and an increase and development of working spaces. It is also suggested that mathematics and physics teaching can be outsourced. Projects could run in parallel with courses: to maintain a mutually beneficial relationship between learning of theory and application of knowledge, to have industrial involvement (especially in product development and mechatronics), and to span the entire academic year if possible. Social interaction, traditions, and events should also be supported and promoted.

[14] Refers to a tradition where freshmen undergo an initiation of some kind.

Individual comments point out that different kinds of projects can be used to motivate students to attend different courses, and that projects should be used as a medium for students to teach each other elements from their own fields of expertise. The idea of increased project work is highly supported, especially in the cases where projects can be used to support, or even replace, some theoretical parts of courses. One comment implies that the relationships between projects and theory courses should be communicated clearly, in order for them to truly support one another.

4.1.3 Part 3: Putting the plans to Practice

What will you do to ensure that the strategy and roadmap goals are met in terms of engineering education?

Group 7 - Bachelor's Degree Programs: How can it be developed and what are the goals for it by 2020? Figure 36 is a reconstruction of the poster produced by this group.

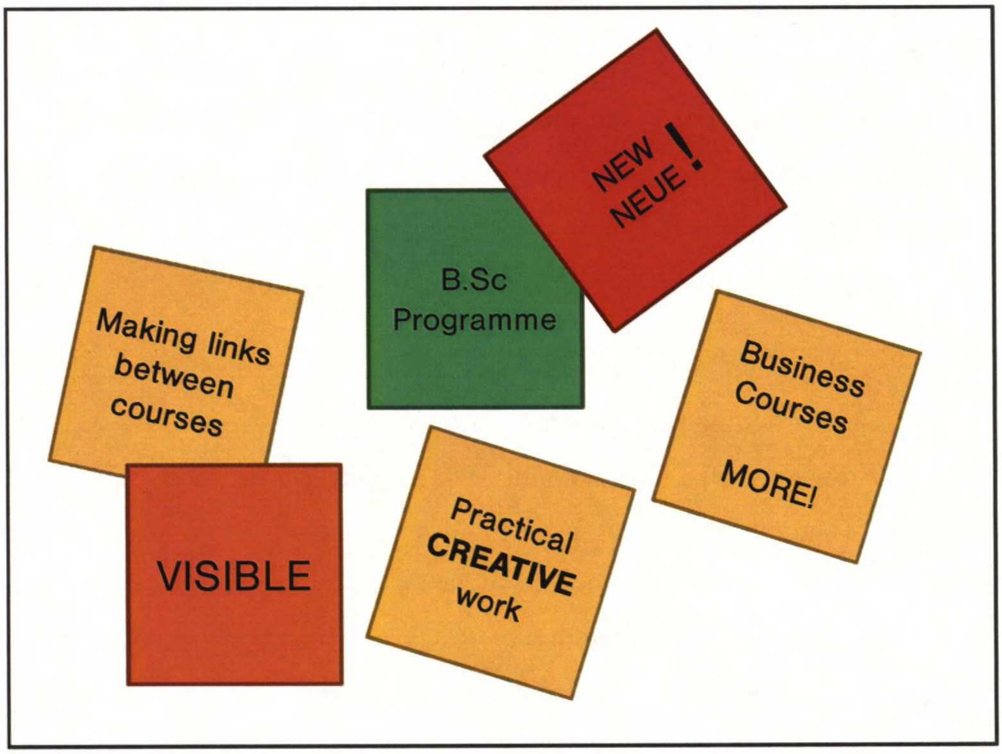

Figure 36 Recreation of poster from Part 2, Group 7 of the workshop

The issues brought up in the poster are visible continuity and clarity between courses, the Bachelor's Degree reform, and more business and creative work. Incorporation of more business studies and creative work should be easy to enforce within Aalto, as long as collaboration can be initiated and sustained between schools. The Bachelor's Degree reform is a god opportunity to exercise a lot of change. That is due to the fact that major restructuring is taking place (Kuuva, 2012).

As individuals, the workshop attendees indicate that more collaboration is needed to make change. There is mention of a planning seminar in November 2011, where professors get updated on the status quo, and discuss future plans while referring to feedback. Assistance of the professors in the planning stage can be done by giving them feedback and enforcing the importance of the big picture.

Group 8 - Master's Degree Programs: How can it be developed and what are the goals for it by 2020? The poster from this group lists the following items:

- Taking care of the bachelor level education quality
- The bachelor's programme should give a more generic background when master's programme is supposed to give more specialized knowledge
- How to help students to be ready to adapt to changes? Generalists vs. specialists
- Prerequisites for students should be carefully evaluated

According to the group, MSc education can be improved by ensuring quality in BSc education, and by turning the BSc programme into a more generic and background-providing program, while maintaining the specialisation aspect in the MSc programme. There also needs to be a way to prepare students for change. Students should be able to adapt, and be able to understand the significance of being a specialist or a generalist. Furthermore, as it has been mentioned by Group 3, links between courses should be streamlined by carefully evaluating course prerequisites.

Individuals in the workshop gave feedback on how they would develop the MSc programmes and some expressed the role that they would be willing to have in the development process. Development ideas include BSc program reform, guaranteeing qualifications during recruitment, specialisation during the Master's Phase, and more cultural diversity. One of the professors lists teaching, international contacts, and collaboration as items that would define their role, one of the faculty members expresses the desire to play a part in the development of a world-class programme, and one of the faculty members describes tutoring and facilitation of student events to be their primary role in the development process.

Group 9 - Working Spaces, Equipment and Services: How should our learning facilities be equipped on a campus level, at a department level, and at a laboratory (ADDLAB) level? The poster from this group lists the following items:

- Multifunctional research/~~teaching~~ learning spaces
- Throw money in the mix €$¥£
- Spaces are to support the ways of working
- 24h/7 => stop idleness / aquarium spaces[15]
- Cafeterias transform into working spaces for the evenings / Responsibilities
- Communal interaction => Networks
- A service attitude as a daily routine
- Dismantling of private fortifications and bunkers – make spaces multifunctional

In this group, the outcome of the discussion is that multifunctional research and learning spaces are needed. It is inspiring to see the word "teaching" crossed over, implying that the spaces are intended for active and learner-centred education. Financial resources for spatial development are needed and the spaces should support multiple ways of working, be constantly accessible, and openly transparent. The idea of cafeterias being transformed into working spaces is already in play (Gryada, 2012).

[15] Refers to transparent spaces

The spaces for future engineering education should support communal interaction and networking, and the faculty should adopt a service attitude as a habit. It could also be good to dismantle private fortifications and bunkers, in order to make space for multifunctional spaces.

4.1.4 Other Observations and Feedback

Observations from the Teambuilding Lunch: The overall impression of the participants as team players is good. Given the space for manoeuvring, as many participants as possible were involved in food preparation. Around one third of the participants were actively involved in food preparation. Some were more active than others. The general spirit of the participants is good. Participants discussed about topics relating to the workshop, as well as topics that did not relate to the workshop. Unrelated topics had to do with personal interests of the participants, practical and current work issues, and the food being prepared. There were no complaints about the types of food or the amount. The participants managed to cook to everyone's taste and satisfaction.

Feedback from the participants is generally good. The average grade given for the workshop is 3.8 of 5. All feedback providers indicated that the workshop is useful, a suitable format for subjects other than CDIO, and should be organised 1-3 times per year. If organised again, suggestion given for the next workshops theme are:

- Project selection
- Integration of international operations
- Integration of research and education
- How, and on what level, to use CDIO
- BSc programme
- Workspaces
- Student-oriented thinking
- Ethics

- Cultural identity
- Leadership skills

In their free words, participants express that the programme should give students more room to make mistakes, more freedom to learn, by e.g. applying Freinet or Montessori pedagogy[16], an opportunity to be involved in research as a part of education, and awareness of the generalist vs. specialist path. A remark on the workshop content is that the topics were interesting, but too broad for the short amount of time. Also, a remark is made on the structure if the workshop: It would be nice to close each part with a small general discussion with other groups. One of the participants expresses that the teambuilding experience with the food was nice.

4.2 Case Studies: Observations Regarding Best Practice

To have multiple points of views in the case studies, the exploration of the TEE reports is complemented with a brief summary of my personal experiences as a student and faculty member of KoRa.

In the end of 2010, certain degree programmes in Aalto were enlisted to participate in the Teaching Evaluation Exercise (TEE). This is a two stage exercise; in the first stage, an evaluation team, comprising of faculty and students, carry out self-evaluations of their degree programmes, and in the second stage, groups of visiting panellists evaluate the degree programmes and submit a report. As a result, there are two TEE reports that are relevant to this study:

- TEE Self evaluation
    - Outcome of the first stage of the TEE
    - Evaluation team comprises of faculty and students
- TEE Report

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[16] Social and active learning by doing in groups, without limitations, following paths of natural curiosity (self-directed content), and experiencing (Hout-Wolters, et al., 2000). Based on constructivism.

- Outcome of the second stage of the TEE
- Evaluation team comprises of an international Panel which includes a Finnish academic member and a Finnish student member
- A student feedback report is also associated with this

The basis for conducting the evaluation is strategic; Aalto aims to maintain an encouraging atmosphere for continued learning (Raevaara, 2011). The self-evaluation report is used to roughly evaluate KoRa against CDIO standards, and the final TEE Report is used to list and analyse best practices in Aalto. Figure 37 summarises the TEE process.

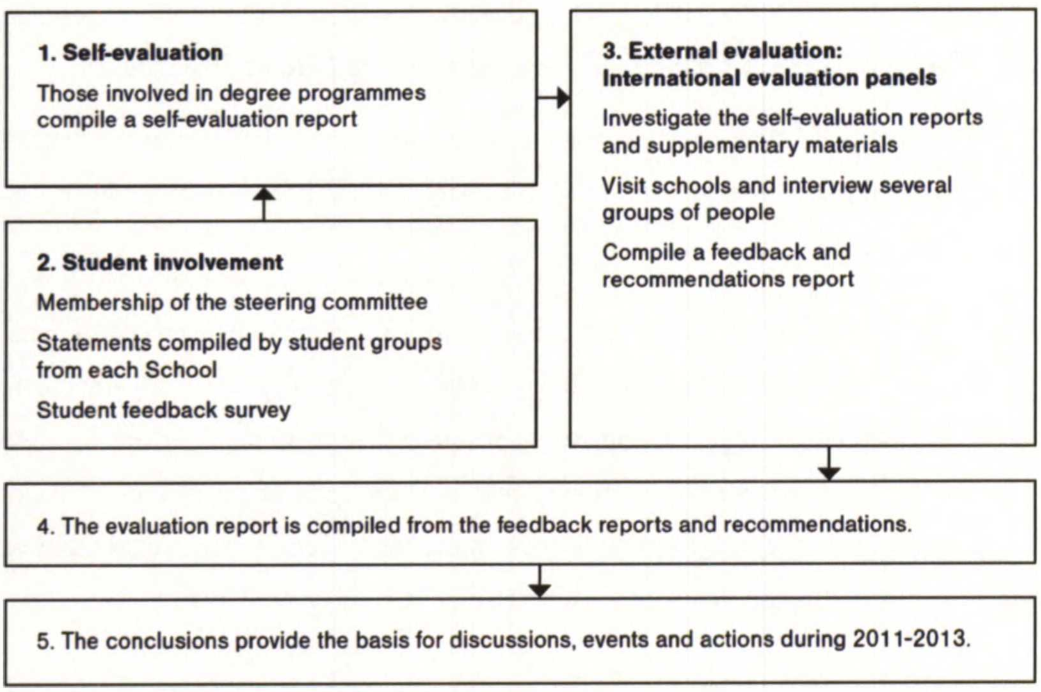

Figure 37 Implementation of TEE (Levander, et al., 2011)

4.2.1 TEE Reflection: Level of CDIO Compliance at KoRa

The following analysis is conducted by picking out the points from the TEE analysis that deal each category of CDIO standards. This analysis points out the areas that are in need of development.

Observations from Programme Philosophy (Table 5):

- The written goal of KoRa is focused on engineering science. This however, agrees with the Aalto strategy. Despite stating that the focus is on engineering research, there is a lot of evidence in the document that prove that educating skilled and professional engineers for the industry is a central part of the programme's activity. This is also desired by in the Aalto strategy (Aalto University Strategy, 2011).
- The CDIO standard can be considered fulfilled

Table 5 TEE Reflection on KoRa's Programme Philosophy (CDIO Standard 1)

KoRa TEE extracts (Aaltonen, et al., 2011)	**CDIO** **(Crawley, et al., 2007)**
Goal: provide the highest education for mechanical engineering based on mechanical engineering research **Mission:** promote mechanical engineering knowledge and skills in a scientific manner in cooperation with industry and society **Objectives:** guide students in the development of a profound understanding of engineering careers | offer student creative and scientific means to develop their practical problem-solving skills	**Overall Goal:** the essence of engineering professions has to be conveyed and practiced in engineering education | graduate engineers who can engineer **Goal 1:** deep working knowledge of fundamentals **Goal 2:** lead in the creation and operation of new product, processes, and systems **Goal 3:** Understand the importance and strategic impact of science and technology on society

Observations from Curriculum Development (Table 6):

- The continuity of the programme corresponding to CDIO Standard 3 has been subject to some negative feedback because of gaps (time gaps and content caps) and overlaps between courses in the assigned curriculum (Aaltonen, et al., 2011).
- The gaps can be fixed by adding additional courses or exercises as suggested in Figure 38 (Aaltonen, et al., 2011).
- These CDIO standards are partially fulfilled by KoRa. The following issues need to be fixed:
    - Gaps: time and knowledge gaps between courses

- Clear indication of how human and professional skills are integrated into the curriculum
- An internet based system for managing courses, their content and their relationships

Table 6 TEE Reflection on KoRa's Curriculum Development (Standards 2, 3, and 4)

KoRa TEE extracts (Aaltonen, et al., 2011)	**CDIO** **(Crawley, et al., 2007)**
Intended learning outcomes: **Personal (and technical) skills:** scientific thinking and working | creative problem solving application of existing scientific knowledge and methods | advance computer science skills **Professional skills:** ability to understand mechanical engineering problems from the perspective of users, the environment, and technical and social systems | work as an expert and developer of their own field | project management expertise | understanding of economic affairs | skills for challenging theoretical professions and practical occupations **Interpersonal skills:** having sufficient language skills for operating nationally and internationally | oral and written communication | teamwork capabilities The definition of these outcomes is based on a long-term collaboration with industry, society, and the international scientific community	**Standard 2:** learning outcomes should be linked so that they are consistent with the programme goals. Also, they need to be validated by programme stakeholders
Feedback from the industry that concerns scientific or interpersonal skills is considered and, where appropriate, integrated into the curriculum **Curriculum management:** a new internet-based curriculum development tool is required to administrate the wide and fractured course spectrum. A lot of information is already attainable on the current database system (Oodi) but the program does not provide a working tool for curriculum development.	**Standard 3:** there needs to be a sense of continuity in the programme, also, development of human and professional skills should be integrated into the engineering programme's curriculum
One of the objectives is to create a solid foundation of fundamentals, and to have mechanical engineering introduction courses that establish professional special know-how of mechanical engineering and inspire lifelong learning	**Standard 4:** an introductory engineering course employs PBL

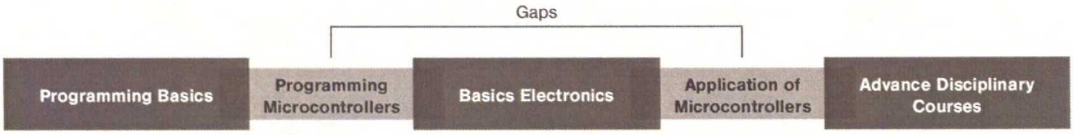

Figure 38 Gaps knowledge between courses can be filled with PBL simple exercises (based on Aaltonen, et al., 2011)

Observations from PBL and Working Spaces (Table 7):

- In terms of spaces, there have been many developments at KoRa that have been inspired by the Aalto Design Factory. There have been two Learning Hub renovation projects in K1, the main building of mechanical engineering (Aalto Design Factory - We Inspire, 2012) (Gryada, 2012). The latest development in education and applied research facilities is the Aalto Digital Design Laboratory (ADDLAB[17]).
- The aspiration of having up-to-date computer programmes is a quality that ADDLAB will develop in the field of design and fabrication.
- ADDLAB will also offer new possibilities in terms of resources and spaces for education and research in the interdisciplinary field of digital design and fabrication
- These standards can be considered fulfilled, or in the process of being fulfilled. Lecture spaces still need to be rethought.

[17] Aalto Digital Design Laboratory is a new interdisciplinary platform for applied research, education, and industrial collaboration. The focus is on computer-aided design and fabrication, material technology, and the cultural implication of new and powerful digital design and fabrication technologies. (http://addlab.aalto.fi)

Table 7 TEE Reflection on PBL and Working Spaces at KoRa (Standard 5 and 6)

KoRa TEE extracts (Aaltonen, et al., 2011)	**CDIO** **(Crawley, et al., 2007)**
In many courses lectures are complemented with exercises, demonstrations, hands-on training in laboratory projects, etc. Advanced courses typically use different types of instructed or independently managed student projects. Real-world problems are prioritised as project. Project briefs obtained from industrial partners commonly used as they are. Advanced courses may apply portfolio creation, prototype and test equipment building, modelling and simulation, utilisation of virtual networks, and complete product development projects with industrial partners. The M.Sc. thesis may also include experimental approaches when applicable. Most M.Sc. thesis topics are obtained from the industry.	**Standard 5:** it is ideal to have design-implement experiences through the duration of the degree programme
Aspirations: access to up-to-date computer programs in different fields so that the students can become accustomed with the modern tools used in industry and research | well equipped laboratory facilities for research and experiments by students especially those in application oriented engineering studies | facilities that support learning by practise| There are libraries, lecture rooms, laboratories, tools and equipment, studios, computers and online learning material.	**Standard 6:** the school facilities need to support and encourage hands-on learning in teams in environments that have spaces to support ideation, engineering design, prototyping, and testing. The facility should also cater for social interaction, personal learning, and, if possible, flexible access to tools and access beyond normal working hours.

Observations from Teaching and Learning (Table 8):

- Aspirations are towards improving the quality of teaching material. That the aspiration should be towards improving the quality of learning, by e.g. the use of active and experiential learning methods, when applicable.
- Lecture spaces need to be rethought; fewer auditoriums and more flexible spaces that support versatile use of activating and interactive teaching and learning methods
- Clear indication, of how human and professional skills are integrated into engineering courses, is needed
- Work is needed to formalise the integration of human skills into engineering education. Professional skills are well integrated; however there is always room for improvement

- These standards are partially fulfilled. For many courses, the mentioned improvements need to be made in order to fully comply to the best practices of these standards

Table 8 TEE Reflection on Teaching and Learning at KoRa's (Standards 7 and 8)

KoRa TEE extracts (Aaltonen, et al., 2011)	**CDIO** **(Crawley, et al., 2007)**
Aspiration: there should be financial resources for hiring enough teachers, so that the classes wouldn't be huge and impersonal mass lectures. The teachers should be able to prepare for their lectures, update their teaching material properly, and have enough preparation time to ensure quality of teaching	**Standard 7:** there needs to be clear integration of human and professional skill development into the engineering courses. Students perceive human and professional skills as integral parts of engineering
Challenge: a large student teacher ratio, in certain courses, makes the adoption of activating teaching techniques challenging. Furthermore, teaching facilities mainly facilitate lecture based teaching instead of supporting the use of activating methods **Examples of best practice**: the Product Development Project course (PDP), which spans over the whole academic year, gathers multidisciplinary student teams of 8-10 engineering, economics and industrial design students to work together on projects based in Aalto Design Factory. The aim is to producing a functioning prototype and technical project documentation. Project results are presented also in front of a large audience and media in an annual gala. For some students, the project course is supported by a simultaneously running Product development theory course. The same principles, with modifications, are applied e.g. on the Mechatronics Project course. Both courses are master's level courses.	**Standard 8:** teaching and learning is based on active and experiential learning methods

Observations from Faculty Development (Table 9):

- Again, the aspiration for improving lecture quality is great; however the aspiration should also be about including learner-centred methods such as PBL and in-class discussion
- Enhancing collaboration between faculty could improve a lot of issues:
    - Collaborating to create a truly integrated curriculum
    - Sharing of best practices in education
    - Getting assistance on challenges
    - Collaboration to update intended learning outcomes

- Before these standards can be fulfilled, attitudes need to change; everybody involved in teaching should adopt a learner-centred philosophy when planning and practicing teaching. There needs to be a widespread understanding that pedagogical skills are valuable.

Table 9 TEE Reflection on KoRa's Faculty Development (Standards 9 and 10)

KoRa Extracts from TEE reports	**CDIO** **(Crawley, et al., 2007)**
Strength: Teachers are stated to be easily accessible by students (Levander, et al., 2011) **Aspiration:** meeting points where teachers could share their knowledge and experience with fellow teachers (a new occurrence, "DF teacher forum" at Aalto Design Factory, serves this purpose) | lecturers should be given proper training in giving lectures that will keep the students focused; lectures should be given by people who can actually teach, instead of people who know enough about subject to talk about it for hours. (Aaltonen, et al., 2011)	**Standard 9:** actions that enhance the faculty's competence in human skills, and professional skills for engineering
Challenge: It is difficult to change the old habits; new ideas on teaching are not always well-received. Knowledge on degree specific research findings is well disseminated through teaching theme days. General knowledge on latest pedagogical findings, and good teaching practice is mainly disseminated through courses offered by OpeTuki, the Teaching and Learning development Unit. A wide spread dissemination of best practice is not possible, as only a part of the teaching staff participates the training. (Aaltonen, et al., 2011)	**Standard 10:** actions that enhance the faculty's competence in providing integrated learning experiences

Observations from Assessment and Evaluation (Table 10):

- If KoRa continues to iterate on this study, Standard 12 is fulfilled
- There is a lot of evaluation on the organisational structure in the TEE-project. In future projects, it will be easier to concentrate on education rather than organisation. On the other hand, it is important to be aware of development needs that are on the organisational level.
- With the current rate of evaluation and reform, the programme evaluation standard (CDIO standard 12) is easily fulfilled. Nevertheless, continuity of programme evaluation and development needs to be assured
- There is a lot to improve on for student evaluation (CDIO standard 11) to be at a satisfactory level:

- Evaluation should be planned with the learning outcomes and teaching methods (Figure 47 on page 109) (Crawley, et al., 2007)
- Evaluation should support the learning process (Biggs, et al., 2007)

Table 10 TEE Reflection on KoRa's Assessment and Evaluation (Standards 11 and 12)

KoRa (TEE extracts)	**CDIO** **(Crawley, et al., 2007)**
Challenge: Old fashioned attitudes and the habit of using only numerical assessment needs to be readjusted in favour of individual oral feedback (time allocation for this is challenging however). **Written feedback:** involves scores for course subtasks such as assignments and exercises, written comments on large student assignments, and written statements in case of thesis work. **Peer assessment:** involves student commentary about subtasks such as seminar presentations and also regarding bachelor thesis work, in which peer assessment is a part of the final graduation process. **Discussions with teachers:** involves commentary and instructions on course subtasks such as exercises, extensive assignments or seminar presentations, as well as guidance during the thesis compilation. **Non-interactive procedures:** utilisation of web-based systems such as Noppa or email, or even physical bulletin boards to bring out the feedback. **Interactive procedures:** more or less non-systematic face-to-face commentary. **Peer assessment:** follow a systematic procedures where the commenting student or students are predetermined and sessions steered by teaching personnel. The department recognises the need for improvement in student evaluation practices. (Aaltonen, et al., 2011)	**Standard 11:** students are assessed on all aspects of their development and achievement of learning outcomes. Feedback is used as a part of the learning process
The TEE-project: has improved cooperation with in the Mechanical engineering degree programme. The discussions within TEE working groups have catalysed many development proposals that have been documented. The Teaching Evaluation Exercise is the first step in the right direction to improve teaching activities towards the world class educational standards. **CDIO:** This work acts as the first prototype of evaluating KoRa against the CDIO standards. **Aspiration:** In the future, there is the need for a budget directed to funding teaching and learning development programmes. (Aaltonen, et al., 2011) There has also been one prior evaluation and self-assessment study (Fonselius, et al., 2001). **Plans for repeated evaluation:** This first TEE-project concentrated on the teaching procedures. In the future teaching evaluation it is important to focus also on the content and the substance of the teaching. It is more useful to improve the teaching methods, contents of the lectures, and pedagogical capability of the teachers than to evaluate the organizational structures and practices (Aaltonen, et al., 2011)	**Standard 12:** the educational programme is constantly evaluated against these standards and improved

To summarise the reflection of KoRa's TEE evaluation against the CDIO standards, Table 11 and Figure 39 give an overview. The evaluation is based on a CDIO self-evaluation scale (Crawley, et al., 2007):

0. No initial (programme-level) plan or pilot implementation
1. Initial plan and pilot implementation
2. Well-developed plan and prototype implementation
3. Complete and adopted plan and implementation in place
4. Complete and adopted plan, implementation and continuous improvement process in place

Table 11 CDIO rating for KoRa complemented by Figure 39

CDIO Standard	Rating
1 Programme Philosophy (The Context)	3
2 Learning outcomes	3
3 Integrated Curriculum	2
4 Introduction to Engineering	3
5 Design-Implement Experiences	3
6 Engineering Workspace	3
7 Integrated Learning Experiences	2
8 Active Learning	2
9 Enhancement of Faculty Skills Competence	3
10 Enhancement of Faculty Teaching Competence	1
11 Learning Assessment	1
12 Programme Evaluation	3

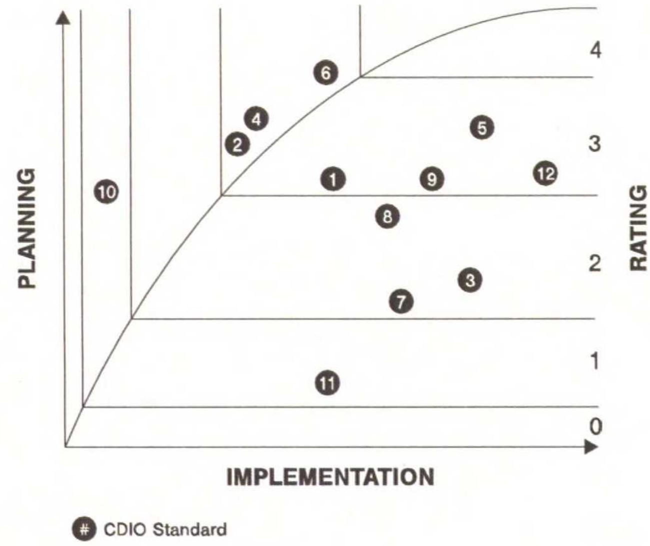

Figure 39 Rating scale for CDIO evaluation. Refer to Table 11 for respective CDIO standards (figure based on Crawley, et al., 2007)

4.2.2 TEE Report: Best Practices in Aalto University

The CDIO Standards give direction; however, to implement best practices that will fulfil the standards, there is a need to search for best practices, which can yield results that can be studied and learned from. This section covers the exploration of best practices in Aalto, which are picked out from the TEE panel's thorough analysis of teaching in Aalto. In their report, they list the best practices that they have discovered while observing Aalto (Levander, et al., 2011). Figure 41 is a summary of the best practices discovered that are relevant to KoRa. An interim process (Figure 8 on page 14) is applied to the data collection and analysis of best practices. The result is a series of best practice cards that can be used to identify best practices and find their practitioners within Aalto. The final process is carried out as follows (Figure 40):

1. The TEE Report (Levander, et al., 2011) is read through and 284 best practices are picked out from the TEE report. These are practices that got praise from the panels of TEE evaluators
2. The collected best practices are evaluated

a. By asking "What is the practice fundamentally about?" the best practices are categorised into 23 reoccurring themes that represent what the practices are fundamentally about.
b. Simultaneously, the CDIO standards that relate to each practice are noted

3. Certain attitudes and circumstances are needed to host best practices. Four categories are created to represent these attitudes and circumstances. The attitudes that relate to each practice are noted. The four categories of attitudes are:
   a. **Flexibility:** students have freedom to study flexibly and possibilities to plan custom combinations of courses
   b. **Blended and personalised learning:** students develop human and professional skills in their disciplinary courses. Teaching and learning methods can be varied to suit the learning habits of different students
   c. **Collaboration:** there is a sense that faculty communicated across research areas, departments, and schools in order to create coherent curriculums and avoid conflict
   d. **Openness and Transparency:** knowledge and best practices are shared, resources are not hidden from others, needed information is available
4. Tools are needed to facilitate the attitudes. Three tool sets are developed: **Virtual Tools**, **Physical Tools**, and **Intellectual Tools**. These tools are developed in Section 6. The virtual set of tools makes use of latest developments in educational ICT[18], the physical set of tools are inspired by good practices in development of working spaces, and intellectual set of tools are a collection of organisational changes needed for reforming engineering education.

[18] Information and Communication Technology

This four step process is visualised in Figure 40. The interim collection and analysis process entails that these four steps take place simultaneously; however, in the overall timespan of the process, focus shifts from Step 1 to Step 4.

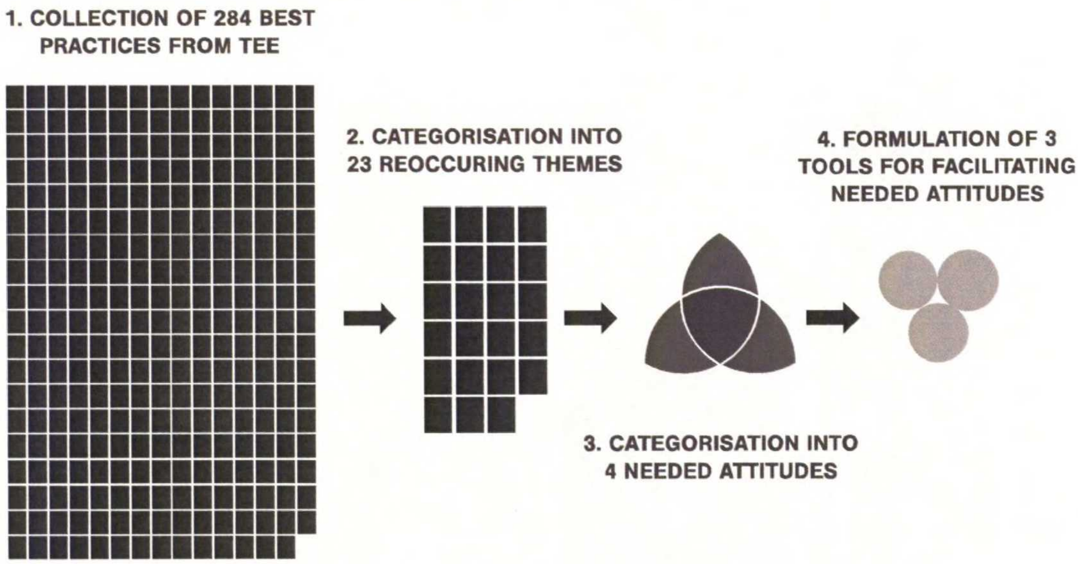

Figure 40 Interim analysis of the TEE Report, while searching for best practice in Aalto

The essential parts of this process are: identifying popular themes, and developing the three needed tool sets. Figure 41 is a visualisation that shows the popularity of the 23 reoccurring themes and the corresponding popularity of the four attitudes within each theme.

This gives an indication of the strongest points of teaching and learning at Aalto, from the point of view of the TEE panels. From the figure, it can be seen that the spirit of reform is strong, as Aalto management is enforcing change. It also shows that despite of strong efforts to develop teaching and learning facilities, the TEE panels have not pointed out many facility-related best practices in comparison to the other beat practices pointed out. These are the two extremes.

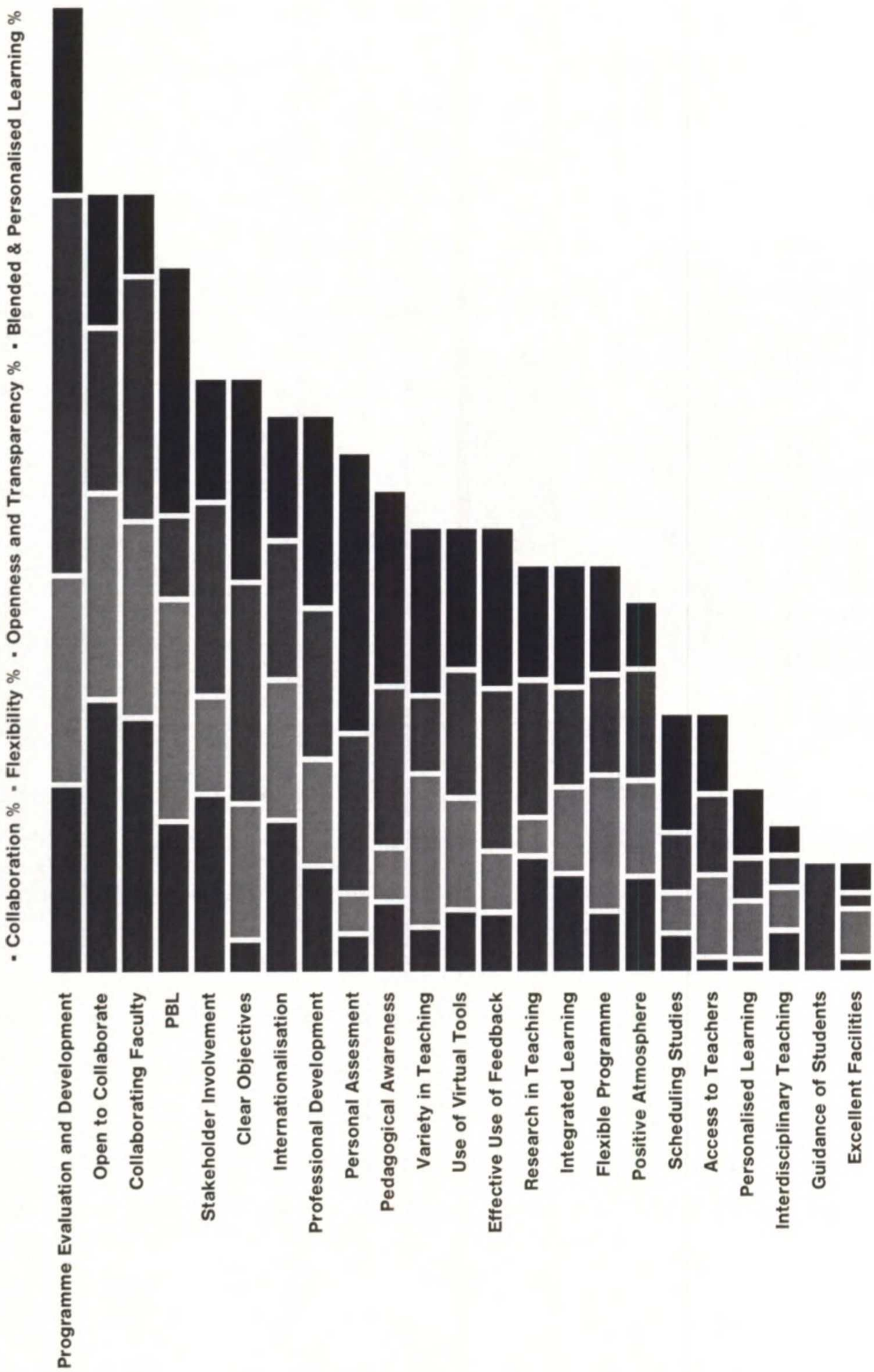

Figure 41 Reoccurring themes and needed attitudes for best practice in Aalto, based on the feedback of the TEE Panel

The relationship between the three tool sets and the four attitudes are sketched using a Venn diagram in Figure 42. Because of the qualitative nature of best practices, the development of this Venn diagram is a very interim and creative process of analysing the trend and patterns within the 284 collected best practices.

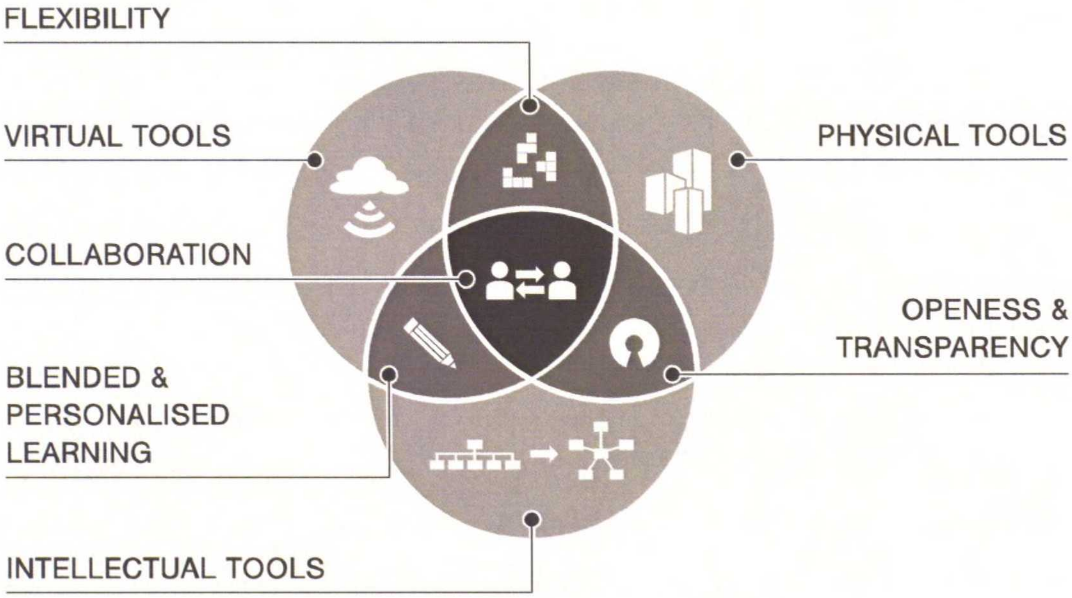

Figure 42 Relationship between the three sets of tools and four needed attitudes

These relationships need some explanation to be clear. Flexibility is an attitude that can be supported by having remotely empowering virtual tools, and spaces that support ad-hoc work, co-creation, and different ways of working. Blended and personalised learning can be supported by inexhaustible virtual learning resources that can be consumed with a chosen amount of repetition and at a chosen pace, and a school organisation that is designed around an inverted classroom where private time is for watching lectures and class time is for guided exercises, discussion, and group work. Openness and transparency can be supported by an organisation that facilitates engaging forums and events for information transfer, and offers spaces that are welcoming, accessible, physically transparent, and equipped to showcase on-going work in a presentable fashion.

Discussion of the individual best practices collected is beyond the scope of this work. However, the best practices are documented as the Best Practice Cards in Appendix B. The best practice cards may be used to locate practitioners within Aalto, or to get ideas from concrete implementations of beat practice.

4.2.3 Personal Experience of Studies

As a student starting in university, I was prepared for an intense scientific experience that would continue by deepening my high school knowledge base of mathematics, physics, chemistry, and economics with the aim of preparing me to carry out a specific engineering task in the industry. I was going to be positively surprised and amazed with the richness, flexibility, and diversity that the educational path I chose – and even more surprised of the opportunities, decisions, and obstacles that it laid in front of me.

Even though I had a firm base of mathematics and physics from studying higher-level mathematics and physics in high school, I found it challenging to put up with the compulsory mathematics courses. Compulsory physics was slightly more effortless and, to an extent, enjoyable since I completed the courses by doing exercises, exams, and lab reports only. My disciplinary knowledge in mechanical engineering relied strongly on the underlying physics courses, with the laboratory course being no exception. Physics labs and reports were my strongest touch point to scientific research and writing. Mathematics felt like it came and went. I believe that the role of the compulsory mathematics in KoRa should be to support physics and the disciplinary knowledge throughout the course of the studies.

I strongly believe that compulsory mathematics should be streamlined to serve the essentials needed to build knowledge in the disciplines, and practiced regularly in order to exercise systematic and logical thinking skills. Development of deeper mathematical skills should be an option like all other studies that do not relate directly to the main intended learning outcomes of the programme. An aspect of mathematics that is bothering, in regard to my degree, is the lack of computer-aided mathematics. The computer is the most frequently used tool in engineering work today, and it is also a very powerful tool for mathematics, yet, there is a large disconnect between mathematics teaching and computers. Math is done on paper, with calculators, which have been downgraded from the graphical calculators in high school, instead of being applied into the writing of algorithms for engineering design, scripting, data analysis, and simulation. It is understandable that math needs to be exercised conventionally; however, the lack of applied computer-aided mathematics remains an enigma.

The clustering of fundamentals in the beginning of the studies had its upsides and downsides. On the positive side, it was a relief to get the calculation intensive work out of the way, maybe because it was highly theoretical and felt impractical. On the downside, there were time gaps between learning fundamentals and using applying them, in the case of the fundamentals that have been used. Another problem was the missing links between courses, namely, programming, electronics, and their link to the rest of my studies. Fortunately, when taking a course called Interactive Prototyping in Design at Aalto TaiK, I learned how to apply my programming and electronics skills in product design, with the help of a coaching engineer at Aalto TaiK. The experience of being taught by an engineer, design professors, and design researchers on one course, was a very rewarding experience. It shows that an interdisciplinary teaching team is capable of a lot more than a team of teachers, all from one discipline – generally, but not always.

While working my way through the fundamentals, I had the opportunity to work in the industry as a Production-line Worker at ABB, and as a Mechanical Design Engineer at Philips Medical Systems. These experiences were an integral part of my education and served as part of my design-implement experience that CDIO strongly promotes. I also had the opportunity to engage in valuable and memorable design-implement experiences within my educational programme. I worked with fellow students from my own field and other fields, and several professionals and leaders from companies to design products, produce prototypes and an art installation, and even redesign the corporate visual identity for big industrial company. The programme and path that I chose has offered an exceptional experience, through which I have developed my human skills and grown personally, professionally, and knowledgably.

As a faculty member I was able to use a lot of my skills in guiding students in their work. Most of the situations where guidance was needed did not relate to my disciplinary knowledge. Most of the issues that needed to be attended to, required organisation, communication, motivation and encouragement, conflict management, and/or ideation. Occasionally students would have problems in engineering, where my disciplinary knowledge was of help. Consequently, I would argue that courses where PBL is the guiding principle in teaching, the faculty's ability to provide professional and interpersonal guidance is very important. This was emphasised while assisting PDP, since students came from different disciplines and cultures, and were commonly experts in their respective disciplinary fields.

Assessment and feedback played a key role in the development of PDP. Feedback sessions were facilitated in the form of four check point meetings with each team, in which the course staff had an hour for discussion, updates and feedback. Informal meetings and conversations that were possible because of the Aalto Design Factory environment, electronic surveys provided additional information, and various presentations and demo days provided good context for peer and public feedback. Furthermore intensive PD6[19] workshops, which summarise the essence of the PDP course and function as a kick-off exercise for each project, are built around intense evaluation and feedback.

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[19] PD6 (Product Design project in 6 hours)-workshop has been developed as a part of the Future Lab of Product Design-research project. The goal has been to develop a training day, which combines all the best known experiences and characteristics from product development projects during the years. The training is intended to be a flexible education and training platform from experienced to novice designers, and also participants who may not know anything about product development. PD6 is an idea generation and evaluation tool.

4.3 Validity of Research

The research findings are a collection of information from selected sources. It is very likely that different opinions are presented in other sources. The research looks into the history of KoRa briefly and in the broad context of TKK as a whole. Historical details, relating to how the current curriculum of engineering had been developed, are not examined sufficiently during this study. Therefore, there is a possibility that some of the arguments raised in this study are contradictory to relevant arguments that have not been discovered during this study. On the other hand, it is possible that the changing environment and context of engineering education counteracts the relevance of the possibly undiscovered and contradictory.

There is an indication that some of the best practices exposed by (Levander, et al., 2011) are not necessarily the best known practices internationally, instead they are the best observed practices within the investigated programmes. In some cases, improvement suggestions are situated into the sections listing best practices. To keep the focus on best practices, the improvement suggestions are treated as best practice mentions of what they suggest. Fortunately, there are only a few occurrences.

In some diagrams the qualitative properties are quantified for analysis. This is highly inaccurate, since it is based on interpretation; however it proves helpful in generating an understanding of the interdependence of the qualities that are studied.

5 Findings: Best Practice in Engineering Education

This section aims to dig down into the direct needs for improvement. Theories on teaching and learning stress the importance of a learner-centric approach to curriculum design that is based on learning outcomes, and the key point to take away from CDIO is that engineers should learn how to engineer (Biggs, et al., 2007) (Fry, et al., 2003).

The Aalto strategy sets the direction of the desired future state. The idea is to become a world-class producer of society-benefitting and national economy-boosting innovation (Aalto University Strategy, 2011). It is important to create a learning-centred culture by readdressing teaching methods, mentoring students, strengthen the link between education and research, actively developing new ways of learning and building expertise, and developing various teaching methods that support personalised learning. Blended learning, and the production and open sharing of teaching and learning materials will support a learning-centred culture.

When appropriate, interim analysis of a finding is done in this chapter. These interim expressions of interpretation or opinion are stated for two reasons: in order for the relevance of the finding to be made clear, and for maintaining the coherence of this work.

5.1 Needed Improvements: Rethinking the Programmes

KoRa has proven to be capable of activity that is above average, and even world-class in some aspects. Based on the stakeholder workshop results strengths of KoRa are: industrial collaboration, practicality, and education for employment. Nonetheless, the academic environment is very dynamic and constant motion is needed for KoRa and its programmes to remain relevant (Aalto University Strategy, 2011) (Crawley, et al., 2007). Management of studies should be easy and intuitive. Planning of studies should evolve around learning outcomes, not courses (Biggs, et al., 2007).

Consequently, a more flexible programme, where courses have more room to change, can be implemented.

5.1.1 Clear Intended Learning Outcomes

The results of the stakeholder workshop point out existing lacks of continuity within KoRa's curriculums.

- The studying of basic courses needs to be redistributed so that fundamental courses support intermediate and advanced engineering courses appropriately
- Visible continuity and clarity between courses needs to be improved
- The Bachelor's Degree reform needs to be acknowledged as an opportunity for making desired changes
- Improved clarity and flexibility is needed in the curriculum, to shine light on what is actually mandatory and what is optional

Furthermore, workshop participants suggest improvements that can be made when restructuring the programme. Some of the improvements listed are: "Subcontracting" of mathematics and physics teaching (math and physics on demand), having projects run in parallel with courses, having an introductory practical exercise, accommodating vocational project briefs from the industry, and the general increase of industrial collaboration. An important point made by a workshop participant is the need for the relationships between projects and theory courses to be communicated clearly; if more theory-supporting project work is introduced, clear correlation is needed for projects and courses to truly support one another.

Students need to understand the significance of their studies in science and technology. As brought up in Figure 43, intended learning objectives are clear to 65% of mechanical engineering students after completing a course and 28% of students after completing the programme (Levander, et al., 2011). I believe that there are two possible reasons: there are gaps between courses, and/or it is unclear to student where their education is going to lead them.

It is clear to me what I should know once I have completed a given course.

It is clear to me what competencies are expected of me once I have completed the entire degree.

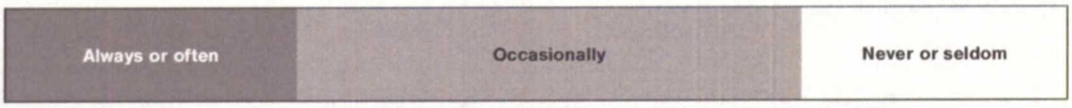

Figure 43 Clarity of learning objectives of courses vs. clarity of learning objectives of the degree programme (based on data from Levander, et al., 2011)

Since the learning outcomes of courses is a lot clearer than the programme's learning outcomes, this might suggests that courses are disconnected and do not contribute towards a clear and coherent learning outcomes. On the other hand, it can be argued that the student's own goals and ambitions after graduation are still flexible, and as a result, the learning outcomes of the programme get blurred. Nevertheless, it is worth working on creating clear and coherent learning outcomes that are coherent throughout the courses in the programme.

> *"Every profession bears the responsibly to understand the circumstances that enables their existence"*

-Robert Gutman (Casey, 2010)

Students have criticised the structure of studies for being unclear and discouraging. Motivation and perseverance in studies can be strengthened by giving students a heightened sense of the value of their studies, challenging them, and providing a rewarding experience. (Erkkilä, et al., 2010) Analysis of the programme structure should start from the very basics: discussing and explaining the circumstances that enable the existence of mechanical engineering professions, the promise of what the programme offers the students, the role of the programme's graduates in the society, and the future of the mechanical engineering profession. In certain perspectives, market-driven technology appears to be a problem rather that an evolving sequence of solutions (Schmidtz, et al., 1998). Such foundational themes of engineering ethics and responsibility should be included when clarifying the roles and responsibilities of engineers. It should also be clarified that most of the study paths are not fixed to specific professions; that some graduates end up in fields that have little of nothing to do with their studies. As Figure 44 illustrates, studies show that 54% of TKK's mechanical engineering graduates of 2003 feel that they use their university-acquired skills in their work, 38% believe the use of acquired skills is occasional, and 8% experience that the acquired skills are knowledge are not put to use (HUT, Innovation Center, 2009).

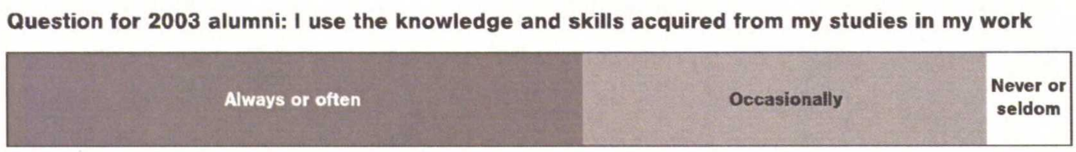

Figure 44 How alumni of 2003 use skills and knowledge acquired from education (based on data from HUT, Innovation Center, 2009)

Over-defined prerequisites and gaps between courses are common problems that can be fixed by applying a curriculum design process that is driven by learning outcomes. Setting learning outcomes is much more than just listing the disciplinary knowledge that students should be able to show in an exam. There are useful taxonomies, such as the SOLO taxonomy or Bloom's Taxonomy (Table 3) that can help in planning studies through learning outcomes. (Biggs, et al., 2007) Figure 45 is an example of how the SOLO taxonomy can be applied in teaching the construction of internal combustion engines.

When a student is selecting their study path, they need to have a clear understanding of the expected learning outcomes. Concurrently, the courses within the chosen path of studies need to consistently train the student towards the set learning objectives (Crawley, et al., 2011). Student learning can improve significantly by defining a consistent study path in a curriculum where there are no knowledge gaps between courses, and there is a constant connection to the real world through PBL (Crawley, et al., 2007) (Fry, et al., 2003).

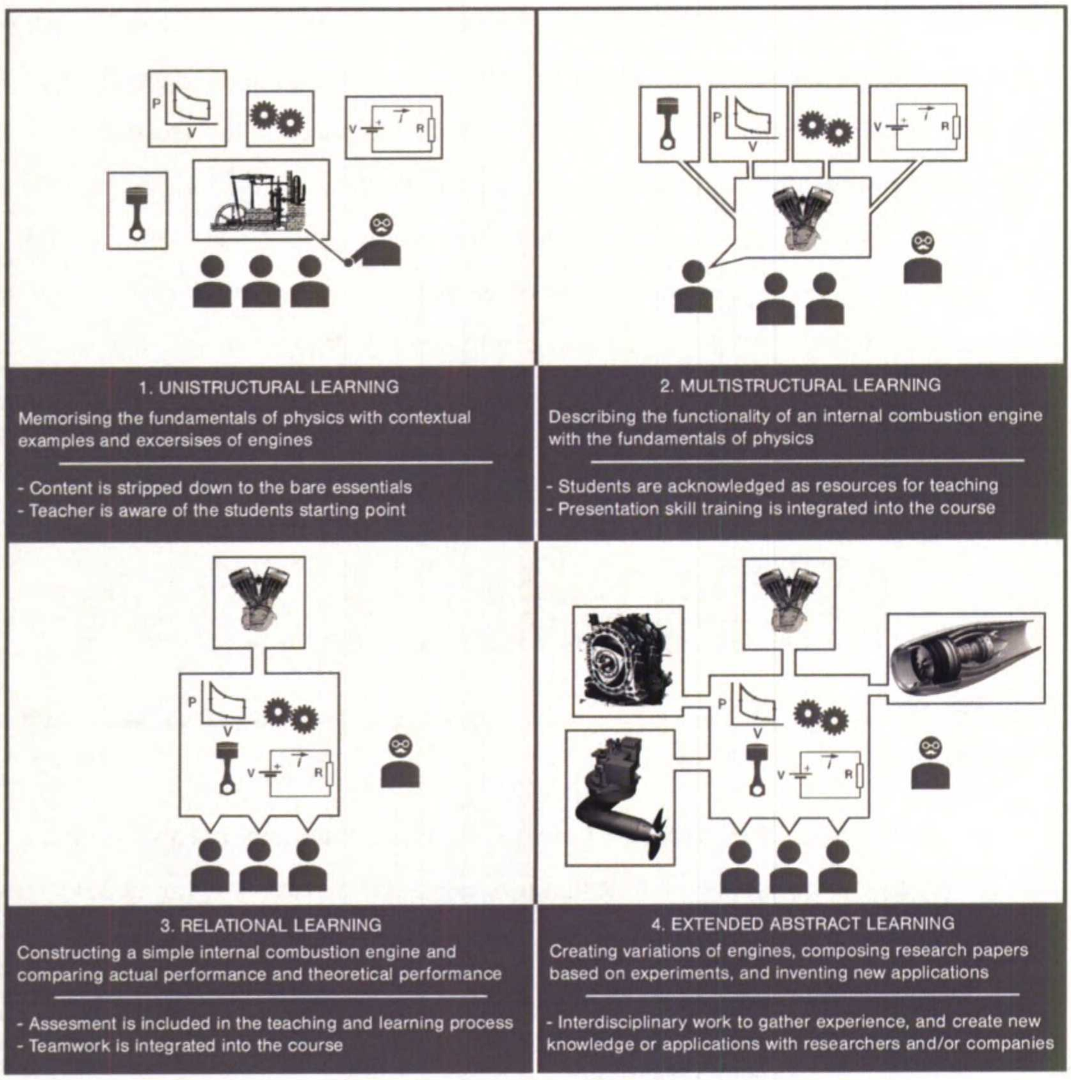

Figure 45 Example of applying SOLO Taxonomy to teaching internal combustion engine technology

As established by the CDIO standards, it is necessary to provide a practical context for engineering education, on which to build disciplinary knowledge (Figure 46). (Crawley, et al., 2007)

The main problem with unaligned learning outcomes occurs in the beginning of the studies – with the fundamental courses (Aaltonen, et al., 2011). Before defining the learning outcomes of the fundamentals, it would be good to define the programmes learning outcomes. That way, it is possible to teach fundamentals that truly support the substance. Clarity and coherence in the programme can also be supported by project work that gives context to theory. As a result the projects can work as the glue between the courses, and as a result learning outcomes can be better aligned. As stated by the workshop participants: projects will support theory, as long as their relationship is clearly communicated.

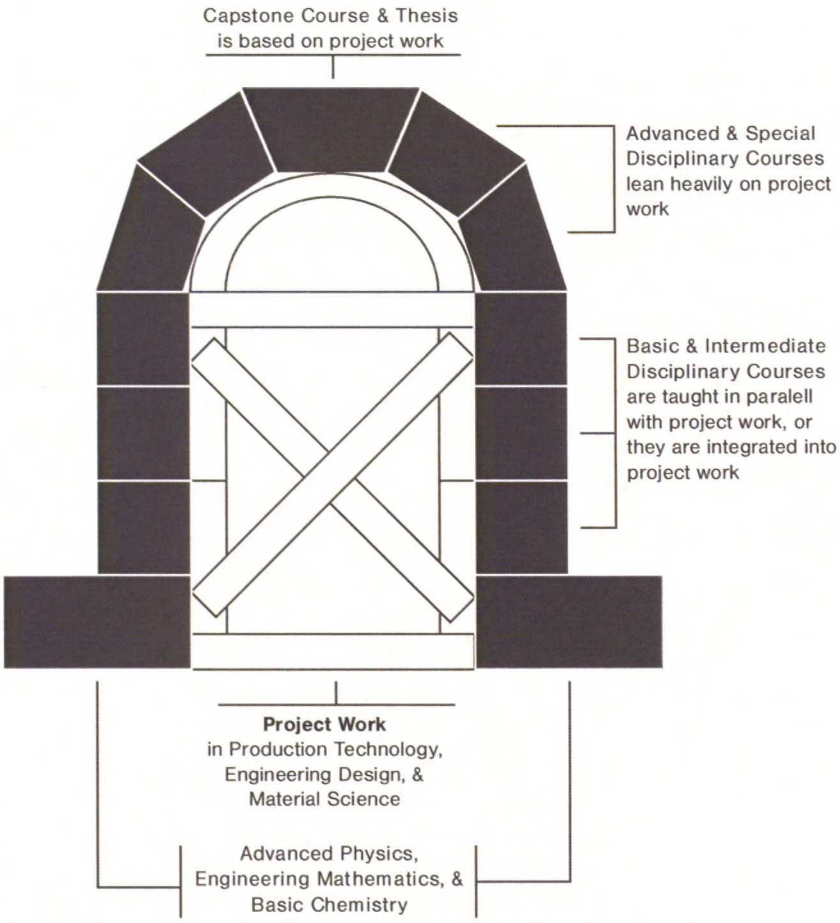

Figure 46 A Metaphor of an Integrated Curriculum where Fundamentals Support Substance (based on Crawley, et al., 2007)

5.1.2 World-Class Quality of Teaching and Learning

The biggest quality concern is in improving the quality of teaching and learning. Personal development of pedagogical expertise starts from acknowledging the assumptions, expectations, traditions, ways of working that operate in the background of one's own field. Pedagogical training and development does not have a negative impact on the development of expertise in the substance that is being taught and researched. On the contrary to having a negative impact, pedagogical training can render new findings, points of view, ways of working that are valuable. (Raevaara, 2011)

Skilled teachers are the backbone of University with a high standard of education. More attention should be paid to the pedagogical skill of new teachers and the continuous development of practicing teachers' pedagogical skills. For constant development of teaching, the quality of teaching and learning needs to undergo continuous assessment. Quality assessment and feedback should be in place to support learning, ensure motivation, and ease the amount of work required to improve quality. (Aalto University Strategy, 2011)

According to the results of the stakeholder workshop, MSc education can be improved by ensuring quality in BSc education, and by turning the BSc programme into a more generic and background-providing program, while maintaining the specialisation aspect in the MSc programme. In any case, the quality of teaching and learning at KoRa is very affected by lack of time and resources (Aaltonen, et al., 2011). To revise, the key factors of improving the quality of teaching are (Fry, et al., 2003):

- Students are acknowledged as resources for improving teaching and learning
- Teachers could be more aware of the students' starting points
- Assessment would be included into the teaching and learning process instead of being a separate tool for measuring performance
- Content would be stripped down to the bare essentials

An issue in KoRa that showed to be in the need of substantial development is assessment. If assessment is done correctly, it can be a significant contribution to the quality of teaching and improved student engagement (Biggs, et al., 2007). Assessment works on two general levels within CDIO: on the course level and on the programme level. Assessment is central to CDIO as it is needed to support deep and integrated learning. On the course level, assessment is aligned with teaching activities and intended learning outcomes (Figure 47) to form the building block for effective teaching. (Crawley, et al., 2007)

Students will learn what they think they are going to be assessed on; therefore, assessment should mirror the ILOs (Biggs, et al., 2007). The pedagogical implications of assessment are explained with more detail in Section 3.3.5. In addition to clarifying the learning curves for students, assessment and feedback are used to constantly evaluate and continuously improve the engineering education programmes. (Crawley, et al., 2007)

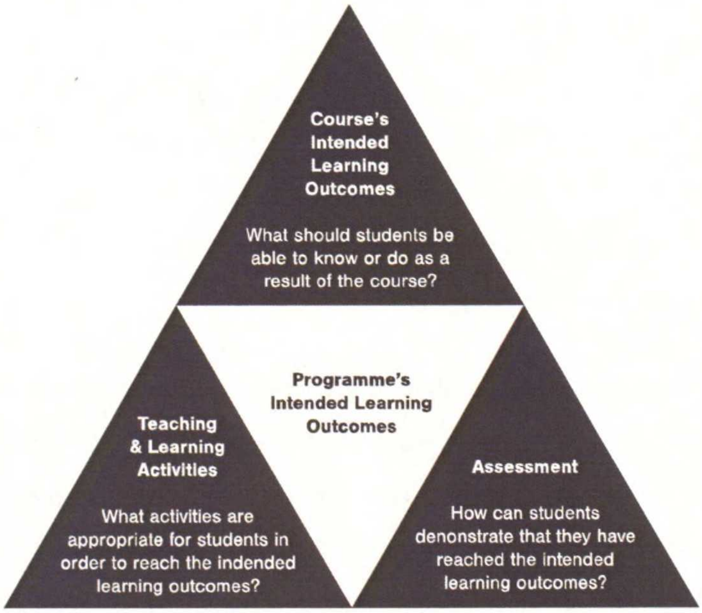

Figure 47 Constructive alignment of outcomes, teaching and learning, and assessment (adapted form Crawley, et al., 2007).

Quality of teaching and learning needs to be improved for courses. Furthermore, the quality of the whole should be given a lot of attention. Having an integrated curriculum is essential for learning that builds of previous knowledge (Fry, et al., 2003) (Crawley, et al., 2007). As mentioned earlier, KoRa needs to fix knowledge- and time gaps between courses, and clearly indicate how human and professional skills are integrated into the engineering courses and the curriculum.

"Some years ago there started to be a lot of negative feedback about teaching of statics and dynamics. This was recognized and the discussion between our teachers and teachers responsible for those courses led to a solution, where we provided practical examples on our field for the teacher who was preparing new course material. This led to increased motivation and better indicated to the students where the equations will be used in practical cases. The same method has also been used for teaching of mathematics." (Aaltonen, et al., 2011)

The fundamentals of engineering should be taught with professional examples from real life. These examples create a correlation between theory and practice. Correlation between technical expertise, professionalism, and human skills is also needed. It is a common misconception that technical and practical skills alone are the skills required for engineering. However, communication skills, teamwork experience, ethics, and attitudes should be developed as a part of engineering education. Teaching these skills in separate courses may imply that they are not an integral part of an engineer's skill set. (Crawley, et al., 2007)

The human element in engineering education is important because engineering professionals need to be able to operate as an integral part of a value network and, in doing so, work closely with customers, supplier, financer, and other stakeholders. Engineers need to understand customer needs, business, and value creation. Strong communication and teamwork skills, ethical responsibility, and understanding of cultural diversity are essential for engineers to operate in the modern globalised world. Expertise is a social phenomenon where these core skills and disciplinary knowledge are used to contribute to society. (Korhonen-Yrjänheikki, 2011)

Human, professional, and practical skills, as well as projects can be integrated into disciplinary studies temporally, in parallel, or fully, as illustrated in Figure 48 (Crawley, et al., 2007).

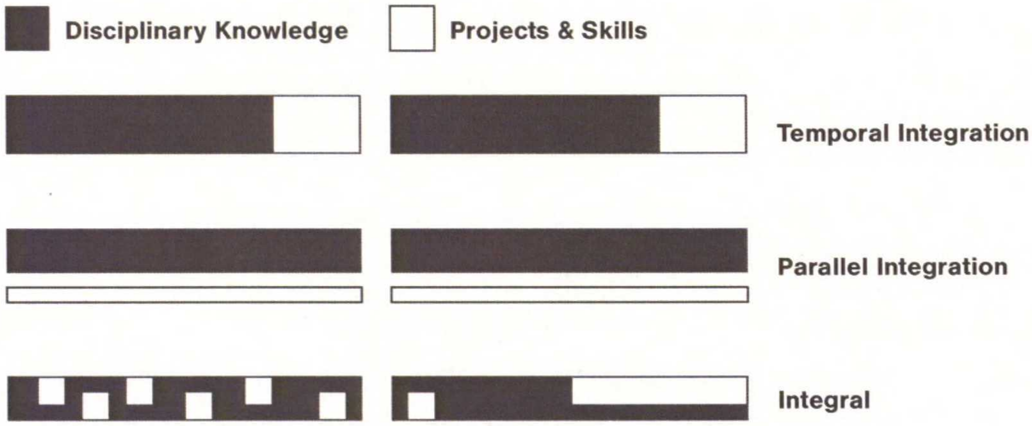

Figure 48 Alternative master plans for curriculum structure (based on Crawley, et al., 2007)

On a more general level, there are four approaches to curriculum design (Figure 49). The first is the traditional university model, the second is a knowledge-based model with integrated projects, the third is a model where project work is central and knowledge is provided for the purpose of assisting the project, and the fourth is a project-based model without any formal disciplinary teaching. CDIO is mainly based on the second model from the right. (Crawley, et al., 2007)

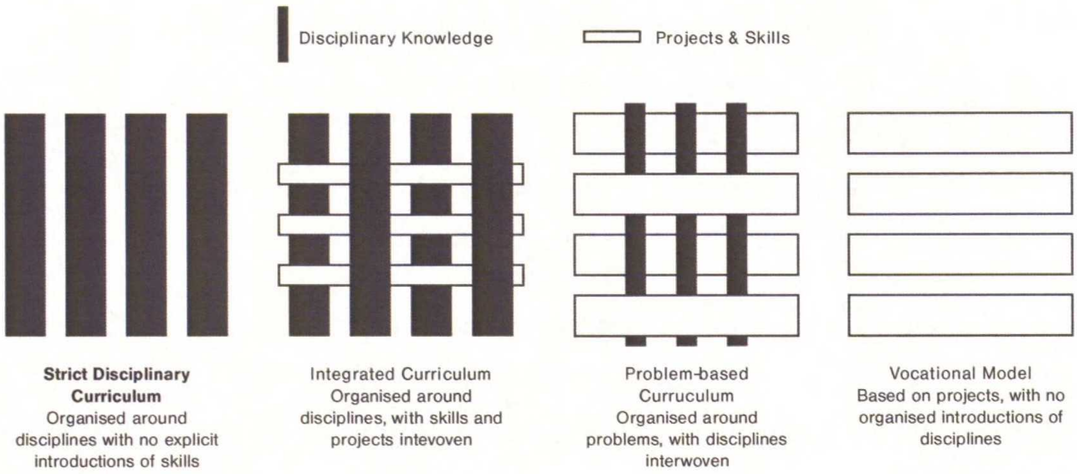

Figure 49 Four approaches to curriculum organisation. Bases on Crawley, et al., 2007

5.1.3 Accessing Students and Alumni as Resources

For everything to operate smoothly, sufficient resources are needed. Resources can be freed up and reallocated, if the acquisition of additional resources proves to be a great challenge. Other ways to ensure more resources are: to discover unused resources, or to combining resources in an efficiency enhancing way. Students and alumni are undiscovered or underused resources in teaching and learning, as well as research.

The results and feedback from the stakeholder workshop bring to attention that students should be acknowledging as resources. According to the workshop participants, students should be motivated by deep learning, the efficiency of teaching needs to be improved, project work and co-creation should be adopted more widely, and additional efforts in assessment and coaching is needed. These needs can be addressed by acknowledging students as resources in teaching and learning (Fry, et al., 2003).

> *"The University also aims to drive the implementation of the newest research findings into society through professional development and continuing education opportunities offered to working professionals." (Aalto University Strategy, 2011)*

One main point of the Aalto strategy is that the university should reposition itself as a producer of knowledge (Aalto University Strategy, 2011). This should not be misinterpreted as implying that producing researchers and conducting research should overrule the need to produce experts for the industry. Engineers from the Aalto's Schools of Science, and formerly TKK, have played a significant role in the technological advancement and welfare of Finland (Nykänen, 2008). Aalto needs to continue producing well-rounded engineers for the industry.

Students and alumni can also be valuable resources for teaching. Some teachers teach what they know, and what they are comfortable with (Aaltonen, et al., 2011). A different stance on teaching would mean that not only would the students learn to get outside of their comfort zones and explore, but the teachers would do the same. The teachers' roles would then shift from being providers of information, to being facilitators, mentors, and curators who would share their judgement, and experience while they discuss new knowledge with students.

As previously mentioned, there has gradually been a move towards mass lectures with growing numbers of participants (Korhonen-Yrjänheikki, 2011). One way to tackle the problem of worsening student to teacher ratios is to acknowledged students as resources for teaching. In the stakeholder workshop, it is mentioned that interdisciplinary projects are a good forum for self-organised teaching by students where students can teach each other elements from their own respective fields of expertise.

Advance student can produce material for students in earlier stages of studies. For instance, graduating student that are working on capstone industrial projects, such as PDP, can take use their brief to generate exam or exercise questions for younger students, and evaluate the mix of creative responses that they get. These responses can be used to generate new ideas for the problem at hand, or for assessment through interaction and feedback that reflects on the students' performance. Similarly, industrial sponsors can contribute to exam or exercise questions directly.

Activating the alumni can open up new possibilities. If alumni are interested in being involved in research, participation should be encouraged. Incentivising the returning scientific papers is one way to encourage involvement. Also involving students in research while they are studying can inspire them to keep contributing to research after graduation and a likely placement in the industry.

5.2 Needed Attitudes: Rethinking the Organisation

The attitudes discussed here are collective attitudes. Before any of these are in place, personal attitudes in general must be swayed. People should have the motivation and drive to passionately pursuer common goals through collective initiatives. For personal attitudes to be in place, and for people to be motivated about driving change, they should be granted an acceptable level of autonomy, training and tools to achieve mastery, and a clear sense of purpose in the work that they are doing. Also, salaries need to be adjusted to a satisfactory enough level, so that the issue of money out of the faculty's minds. (Pink, 2009)

"TEE-project has improved cooperation within the Mechanical engineering degree programme. Many teaching development proposals were documented. The discussions within TEE working groups have catalysed many development proposals. In Aalto University strategy teaching and learning is in essential role. Teaching Evaluation Exercise is the first step to the right direction to improve our teaching activities towards the world class educational standards." (Aaltonen, et al., 2011)

Attitudes in KoRa are changing for the better, as the quote above implies. This is a good sign that the attitudes required are being adopted. Based on the quote above, the vision of where the department is going is known.

5.2.1 Flexibility

Flexibility is essential for two main purposes: for KoRa's programmes to evolve continuously, and for improved student engagement, by providing flexible access to learning material and facilities – providing the possibility of learning when the mind and body are awake and responsive. Based on the stakeholder workshop results, students and faculty need to have an attitude that allows them to adapt to change, rather than resist it. On a positive note, individuals in the workshop express their intentions to drive change, and the need for financial resources for spaces that support multiple ways of working, and cafeterias being transformed into working spaces.

A deep understanding of the fundamentals is the essence of mechanical engineering education (Crawley, et al., 2007). One discovery of this study is that courses occurring later in KoRa's degree programmes are relatively flexible and engaging; however, courses catering to the fundamentals of mechanical engineering, such as physics and mathematics, are the ones that are the least flexible and the least engaging.

Ideally, it would be great if courses were set to provide variable amounts of credits by default. That way, students would be able to partially attend a course by picking out the bits of knowledge that are relevant for the requirements of disciplinary courses and the overall intended learning outcomes of their programme.

5.2.2 Openness and Transparency

The online world is a chaotic system that is beginning to self-organise. There is no doubt that the amount of information available and accessible is growing rapidly. Fortunately, solutions for making sense of the unmanageable amounts of data are being developed. In a world with increasing capabilities in ICT, crowds of people can be coordinated to achieve remarkable things through crowdsourcing, the explosion on information available is becoming manageable as a growing number of people and algorithms are beginning to curate content into manageable and clear packages that people could freely subscribe to. The key to coordinated crowds making sense of the chaotic amount of information is openness. (Castells, 2011) (Vest, 2010)

Transparency is a word that echoes throughout the TEE report and, in general, the mention of the word is used to refer to the lack of transparency, or the need for transparency (Levander, et al., 2011). KoRa and other departments in Aalto need to embrace a culture of transparent openness and collaboration that rewards efforts towards new practices rather than resists change. This will make the organisation more flexible and adaptive to the changing circumstances that enables the existence of professions in the field of mechanical engineering. There is also a need to create a system that allows unique individuals to develop their strengths, exercise their creative and critical thinking, and collaborate with other unique individuals for different academic, professional, and cultural backgrounds (Vest, 2010). This applies for faculty and student alike. These attitudes need to be adopted in order for the future engineers to be capable of dealing with the upcoming problems and challenges, many of which are wicked and unknown; future engineers need to be broadminded and capable of tackling unknown problems by either having a broad cross-disciplinary knowledge base, or by collaborating with a group of people with different approaches, disciplinary backgrounds, and experiences.

Just like companies, universities also need a broad perspective on their markets and opportunities in order to stay competitive. Making use of crowds and communities is one way to broaden a company's perspective. Despite having a large number on internal resources, large companies have a need for opened innovation since they have a tendency to institutionalise. (Blackwell, et al., 2008) This applies for universities as well.

5.2.3 Blended and Personalised Learning: Being Lerner-centric

The purpose of engineering education is to provide students, who are aspiring to become contributing members of society, with engineering skills, expertise, social awareness and a bias attitude towards innovation (Crawley, et al., 2007). The aim is to strengthen productivity and encourage entrepreneurship in an environment that is increasingly based on technology, and technologically complex and sustainable products, processes and systems. To get to this desired state, the quality, nature, and culture of engineering education needs to be improved. In addition to being educationally effective, engineering programmes need to be interesting and true to engineering, so that they would attract and retain motivated students (Crawley, et al., 2007). Focus needs to be shifted away from over-defined prerequisites in the early studies, to engaging activities and learning outcomes.

It is hard to engage every individual student in a classroom. In addition to having different states of mind, being in different moods, and having different concentration spans, people learn at different paces and prefer working in different places. Some require repetition, while some identify patterns and are able to skip ahead. E-learning makes it possible to overcome some differences; however, contact teaching is still needed for social interaction and human preferences. Integrating e-learning and classroom learning can result in extremely effective teaching and learning processes. This is known as blended learning. There are different ways to blend e-learning to conventional learning (Christensen, et al., 2008):

- Enhancing traditional teaching with online tools,
- Having hybrid education, where online teaching can be used to maximise use of space and to tend to larger groups of students,

- Supplemental e-learning, where unprivileged, handicap, or preoccupied students can study remotely

When applying blended learning, students will become more motivated, more engaged, and subject to deep learning of the subject. (Christensen, et al., 2008) As a result, students can be able to grasp the fundamentals of engineering and stay motivated.

There is a need for KoRa to acquire or develop a platform for the virtual component of blended learning. There is bound to be a few dominant platforms for e-learning. The success of the dominant platform will be defined by its ability to evolve, offer functional incentives, and maintain a student-centred focus.

As technology develops things that were previously unimaginable become possible all of a sudden. Most of the 14 Grand Challenges will become less challenging as technology develops. A particularly interesting grand challenge, in terms of this study, is the challenge of advancing personalised learning. The technology for doing so is waiting to be exploited and institutions like Coursera[20], Lynda[21], and Khan Academy[22] have begun to empower student worldwide. E-learning is a disruptive technology in education, that universities must take very seriously (Christensen, et al., 2008).

To become a world-class university, Aalto needs to be among the top universities that provides on-line courses for free. Figure 50 is an array of universities that are collaborating with Coursera to preview the world's best educational content. Being a

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[20] Coursera is *"a social entrepreneurship company that partners with the top universities in the world to offer courses online for anyone to take, for free."* (https://www.coursera.org)

[21] Lynda *"is an online learning company that helps anyone learn software, design, and business skills to achieve their personal and professional goals."* (http://www.lynda.com)

[22] Khan Academy is a free resource *"with a library of over 3000 videos covering everything from arithmetic to physics, finance, and history and hundreds of skills to practice."* (http://www.khanacademy.org/)

contributor to Coursera will give Aalto recognition as a world class university, and serve the strategic goal of disseminating knowledge to society. I strongly believe that Aalto's flagship courses, which are remotely practicable, need to be available to the world – for free. An online course can be considered to as the textbook of this day and age.

Figure 50 Partners of Coursera (Coursera, 2012)

> *"In a world in motion, staying inside any box preassigned by others is a formula for extinction."*
>
> -Garry K. Van Patter (Patter, 2011)

Taking on the grand challenges introduced in the beginning is very ambitious. The knowledge required to tackle those challenges does not necessarily exist within our society, and if it does, it has not yet made it to the reach of the people who have the ambition, confidence, and skills to take on those challenges. The culture of teaching needs to change in order to equip the students with the tools and attitudes they will need while rising up to ambitious global challenged. Students at KoRa need ambition, confidence, and skill-to-scale in order to work both within and beyond the boundaries and possibilities that the consumer culture has created (Patter, 2011). For that to be possible, teachers need to change their stance on teaching by becoming the role models of lifelong learning and international collaboration.

5.2.4 Collaboration

In the spirit of Aalto, research, art, and pedagogy should be merged to create a place that facilitates the collaboration of art and science, and acts as a basis for solving societal issues and working within the various disciplines of Aalto. The performance of education can be monitored by keeping track of teaching quality, student performance, alumni and employer satisfaction, and the proportion of multidisciplinary studies. (Aalto University Strategy, 2011)

In the stakeholder workshop results, it shows that there are a lot of good practices at KoRa. There are group works, presentation exercises, and other kinds of works that develop interpersonal skills. On the downside, many of these exercises are done mostly with other mechanical engineers. To improve on this, collaboration with other schools and departments, to create truly interdisciplinary and realistic group work experiences, is necessary. Also, the participants of the stakeholder workshop suggest that industrial collaboration can be included by progressively increasing involvement of industrial companies in student projects as studies progress and the projects become more professional.

The Programmes for MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design are commended repeatedly, in regard to the Faculty's ability to collaborate (Best Practice Cards 113-124 in Appendix B) (Levander, et al., 2011). They may work as good examples and collaborators when rethinking KoRa's collaborative strategy.

Collaboration in educational development could speed up the development of KoRa's programmes. During the search for material regarding engineering education reform, it became evident that many people are interested in driving change. This is seen in the number of documents that touch on the subject. Consequently, networking has become an important aspect for engineering education reform. Shared incentives and focus is needed to give sufficient momentum to the desired reform, and to fight against resistance to change within the current engineering education systems.

Furthermore, sharing experiences, within a network of engineering educators who are in favour of reform, is a way to spread and test ideas and best practices with effort that is minimised by shared learning. Initiatives, such as CDIO, provide this kind of network for engineering educators and educational facilities that are reforming engineering education (Crawley, et al., 2007).

It would be important to get alumni and industry representatives involved in the development of education. When it comes to defining the learning outcomes of the intermediate and advanced disciplinary courses, stakeholders need to be involved (Crawley, et al., 2007). Also, representatives of the society at large should be considered. Collaboration projects are a good way to have an active involvement with the industry and society. This kind of collaboration is already in play in KoRa (Aaltonen, et al., 2011); however, there is a lot that can still be done together. The development of an engineering programme should be a collaborative process.

Industrial partners also need to be treated as resources for education. Students who partake in work-based learning tend to be more employable, motivated, and skilled (Erkkilä, et al., 2010). Employers value work experience, and students get highly motivated when working. For that reason, work experience is to be placed in the status of learning objectives.

5.3 Needed Tools

Tools for remodelling the organisation and ways of working are needed for real reform to be seen in KoRa's engineering programmes. In addition to rethinking the programme and the organisation, the use of physical and virtual tools needs rethinking.

5.3.1 Use of ICT in Teaching and Lifelong Learning

One of the doors that have been unlocked by developments in information and communication technology, or ICT, is the possibility of e-learning. According to Palomäki, et al., (2010), four environmental drivers are changing the way we learn and work are:

- Abundance of resources and relationships via the internet
- Flexibility and freedom to choose where and when to work and study
- Rising trend of cloud-computing and decentralized IT support
- Growing amount of collaborative work and collaboration between campuses.

It is essential to invest in ICT applications for education, network campuses, share curricula, and improved international cooperation in education (Aalto University Strategy, 2011).

> *"There should be access to literature either in printed or in electronic form... The ICT facilities should be available for students in such a way that they can proceed in their studies" (Aaltonen, et al., 2011)*

Technology will not replace teachers, it will empower them (Cator, 2011). Nevertheless, some lessons or tasks can be taken off the teacher's hands by outsourcing to online resources such as Coursera, Khan Academy, or Lynda. Students can learn independently at their own rate, gain certificates from their efforts on the online courses, and have their responsible teachers approve their certificates. When stuck, students can use the time normally reserved for lectures to tutor each other, and to get guidance from teachers who could be spend less time on lecturing and lecture preparations and more time on tutoring and correcting common misconceptions. Participants in the stakeholder workshop pointed out that students should become familiar with taught content by reading beforehand, so that they can be engaged in discussions afterword. Offering engaging teaching content online and scheduled sessions, specifically for discussion, can induce such student engagement (Cator, 2011).

In the future learning will be (Cator, 2011):

- Lifelong; preschool to end of career
- Formal and Informal; in school and out of school
- Multiple Pathways; multiple instructors for multiple options

- Multiple Devices; multiple environments and sources

For lifelong learning to become a reality, learning needs to be monitored. This is supported by the argument that assessment is a crucial part of learning (Crawley, et al., 2007). A *Learning Positioning System* is a concept that could be adopted in order to map and monitor learning (Cator, 2011). The Khan Academy offers a good example of this (Khan Academy, 2012). To grasp the potential that ICT makes possible for education, the following attitudes need to be adopted (Cator, 2011):

- Access to education needs to be improved
- Education needs to be made transparent
- Focus should be on people and communities
- There needs to be investment in rapid improvement; fast technology transfer (instead of long and controlled trial periods and fixed teaching practices)

In Aalto, there is a need for a virtual tool that, simply put, supports and documents lifelong learning. The tool should be a single interface that integrates curriculum planning, feedback, career profile planning, portfolio building, project creation and communication, and university events and activities. A well-functioning and constantly developing virtual tools can also empower, people by providing reach and freed resources and time. For supporting lifelong learning and planning of ILOs, the concept of STOPS (Software for Target-Oriented Personal Syllabus) has great potential (Paavola, et al., 2011).

The STOPS concept, which is under development, is a pilot of an opened computer-aided multipurpose tool that is to be used as a syllabus planner, and as a tool for developing course content. The objective of STOPS is have a system that is flexible enough to take into account varying needs and expectations of the syllabus by allowing students to control their study path. (Paavola, et al., 2011) The basic concept of STOPS is illustrated in Figure 51. STOPS are a best practice that should be widely adopted in Aalto. It is discovered while browsing the TEE panel's selection of best practices (Best Practice card 265 in Appendix B) (Levander, et al., 2011).

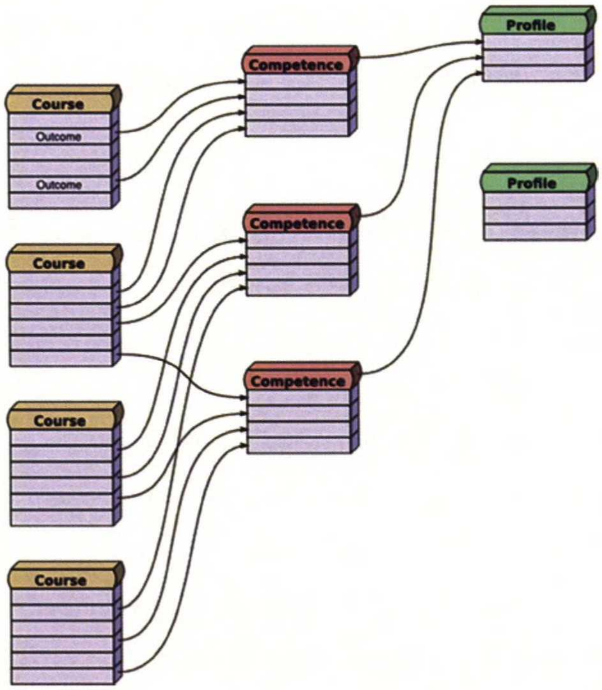

Figure 51 Construction of STOPS (Paavola, et al., 2011)

Looking to the greater society for contribution to teaching and research can be empowering. Since resource allocation is experienced as one of the major challenges in KoRa (Aaltonen, et al., 2011), there is a need for the educational staff to start looking beyond the organisation for resources. Modern information technology may be one of the many enablers of looking beyond the organisation for resources.

In the Aalto strategy, it has been established that *"systems for recording research results, for facilitating distant learning, and for managing research projects necessitate the development and maintenance of high-quality information systems at academic institutions."* (Aalto University Strategy, 2011) This calls for the development and adoption of new integrated virtual tools. The virtual tools extend the reach and the capabilities to plan, share, search, document, or collaborate.

To go back to the point on assessment, there is an urgent need for a functioning feedback system. The problem with the current ones is that that are long, different for each course, and they don't generally evaluate modules or programmes as a whole.

For consistency, there is specific need for a system that allows courses to be compared or evaluated in clusters of modules or programmes as well.

5.3.2 Working Spaces

During the 1980's and 90's, engineers in the industry, government representatives, and university faculty pointed out the prioritisation of theory over practice in engineering education as a pervasive concern. This concern is critical since practice emphasises design, teamwork, and communication skills were in the shadow of theory. These skills have been diminishing from engineering education, despite having been the hallmark of engineering at a time. As a result, tension has built up between theory and practice and reintroducing intensive practice in engineering education has become challenging. To tend to this challenge, the CDIO initiative aims to relieve the tension and satisfy the desired outcomes of both the theoretical and practical education. Therefore, an integrated curriculum, that intertwines project work and skill development into disciplinary knowledge building, forms the backbone of the CDIO syllabus. (Crawley, et al., 2007)

Such work requires facilities that support hands-on working, in addition to contact teaching, and intellectual work. In terms of workspaces, Aalto Design Factory (ADF) is the ideal CDIO working space and has more good practices to share in this category than anything available in easily available CDIO literature.

> *"Design Factory, opened in October 2008, is one of the projects of Aalto University. Design Factory is the symbiosis of the state-of-the-art conceptual thinking and cross-disciplinary hands-on doing. It leads a way towards a paradigm shift in education and business by providing a constantly developing collaboration environment for students, researchers and business practitioners." (Aalto Design Factory, 2012)*
>
> *"PASSION-BASED LEARNING*
>
> *Throughout the year, Design Factory's hallways and working spaces are filled with passionate students having fun while working hard in their numerous academic fields. We encourage all students to challenge themselves in an interdisciplinary*

environment, have the guts to try new things and let ideas fly. Students are given easy access to materials, equipment, spaces and talented people in order to realize their visions through prototyping, as well as opportunities to experience autonomy, mastery and purpose – the crucial blocks of intrinsic motivation. Both interdisciplinary and subject-specific courses of Aalto University hosted at Design Factory aim at provoking child-like curiosity, independent thinking, and problem-based learning. On the other hand, by providing teachers the opportunity to get to know and experiment with the Design Factory ways of teaching and learning, we help to spread a new passion-based learning culture throughout Aalto University." (Oinonen, et al., 2011)

A proper CDIO workspace is worth experiencing. The following points list the essential and serried attributes of a CDIO workspace (Crawley, et al., 2007):

- Essential
    - Facilitate student learning of CDIO skills
    - Encourage hands-on learning of product and system building, disciplinary knowledge and social learning
    - Facilitate group activities, social interaction and communication
    - Provide adequate training opportunities
    - Comply with local health and safety regulations
    - Provide a sustainable resource
- Desirable
    - Organized and managed by students
    - Provide flexible equipment and activities
    - Facilitate access to students outside normal class hours
    - Provide access to modern tools, equipment and software

All of the attributes above are inherent to Aalto Design Factory. In terms of ideation- and hands-on spaces, Aalto Design Factory has plenty of meeting rooms, a machine shop, two electronics workshops, and a heavyweight prototyping area for painting, and dusty / noisy work. Puuhamaa (Figure 52), a flexible space for teamwork, lightweight prototyping and lectures, is particular space in ADF that combined all elements of a CDIO workspace listed above. In the case of lecture spaces, it would be ideal to have a space like TUviisi, illustrated in Figure 53, that facilitates active and interactive learning methods in addition to traditional lectures (Crawley, et al., 2007).

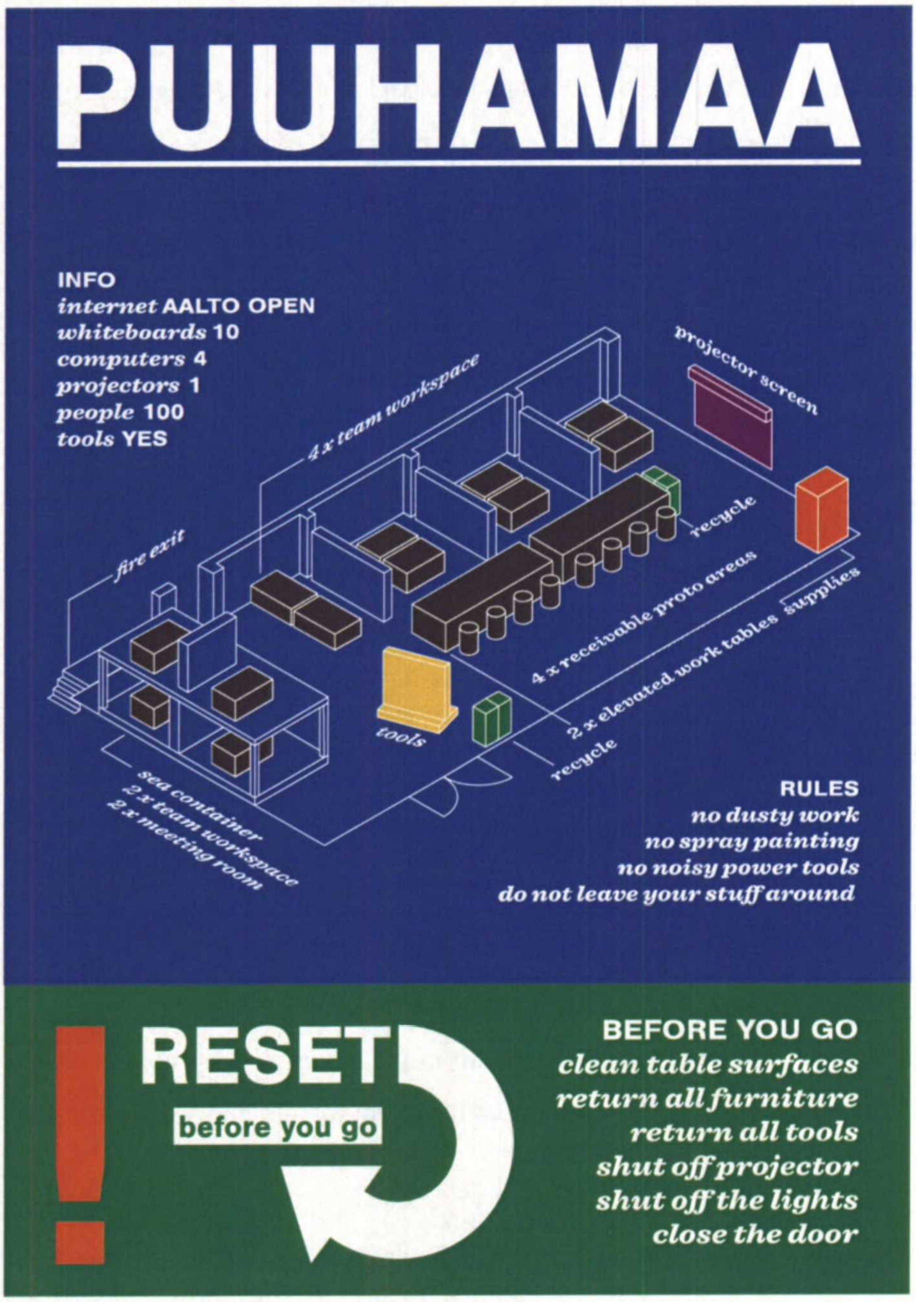

Figure 52 Puuhamaa: the ideal CDIO workspace (Atanassov, 2011)

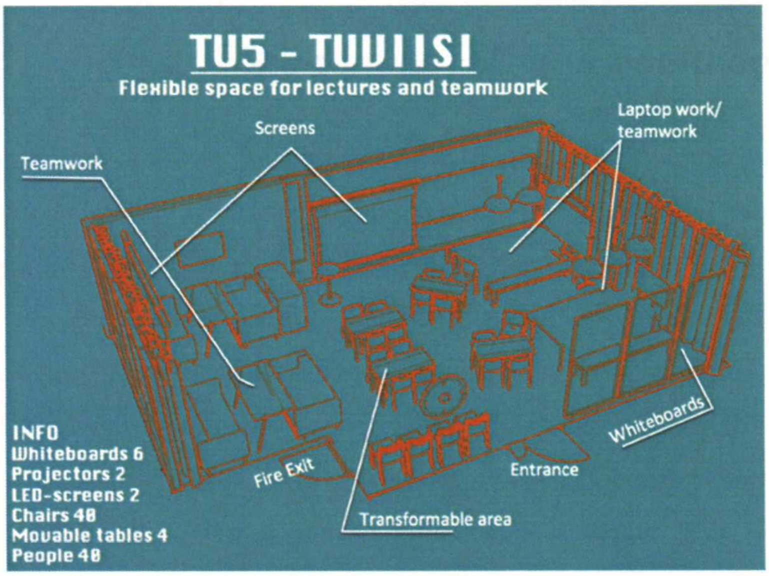

Figure 53 TU5, an example a replacement for small auditoriums (Santamäki, 2012)

There is a lot of very positive spatial development going on at KoRa and supportive facilities. However, lecture spaces need to be developed so that they can facilitate more than just lecture-based teaching. Auditoriums are great for acoustics; however, designing a room to host one central speaker restricts the use of active and interactive teaching and learning methods. The TU5 (Figure 53) teaching and learning space that has been implemented, is a good example of how small auditoriums can and should be transformed, in order to apply more engaging and active teaching methods.

6 Suggestions and Recommendations

The introductory part of this study is concentrated with arguments and explanations that point out why engineering education needs to be reformed within KoRa. The research findings are a collection of detailed and specific areas for improvement that give a good idea on how engineering education in KoRa can be reformed. To answer the second research question (**How can best practices be adopted at KoRa?**), This section introduces tools, followed a series of suggestions and recommendations of what should be done in order to create a modern and evolving learning environment that fulfils selected modern engineering education standards, and conforms to the Aalto strategy.

The path to recommendations and suggestions is a result of a long and intensive study of the literature around the subject of engineering education in the Aalto context, stakeholder involvement, and examples of best practice that helped to develop a set of tools. Figure 54, summarises the path that leads to the solutions presented in the rest of this work. The solution presented contains suggested actions for KoRa that are recommended as immediate action, or actions for the near future.

6.1 Tools for Reform

While searching for best practice in Aalto (process described in Section 4.2.2), three tool sets, for supporting the attitudes needed to adopt best practices, have been conceptualised. In this section, the tools are developed into detailed concepts that are used to generate various suggestions. These tools have been briefly introduced in Figure 42, on page 97, and the writhing surrounding it. The three tool sets overlap to support the four attitudes: collaboration, flexibility, openness, and learner-centrism (blended and personalised learning). One tool sets consist of multipurpose virtual platform, another tool set is a template for physical spaces and facilities, and a third tool set consists of scheduling practices and organisational transformation that is made possible by modern technology, particularly ICT.

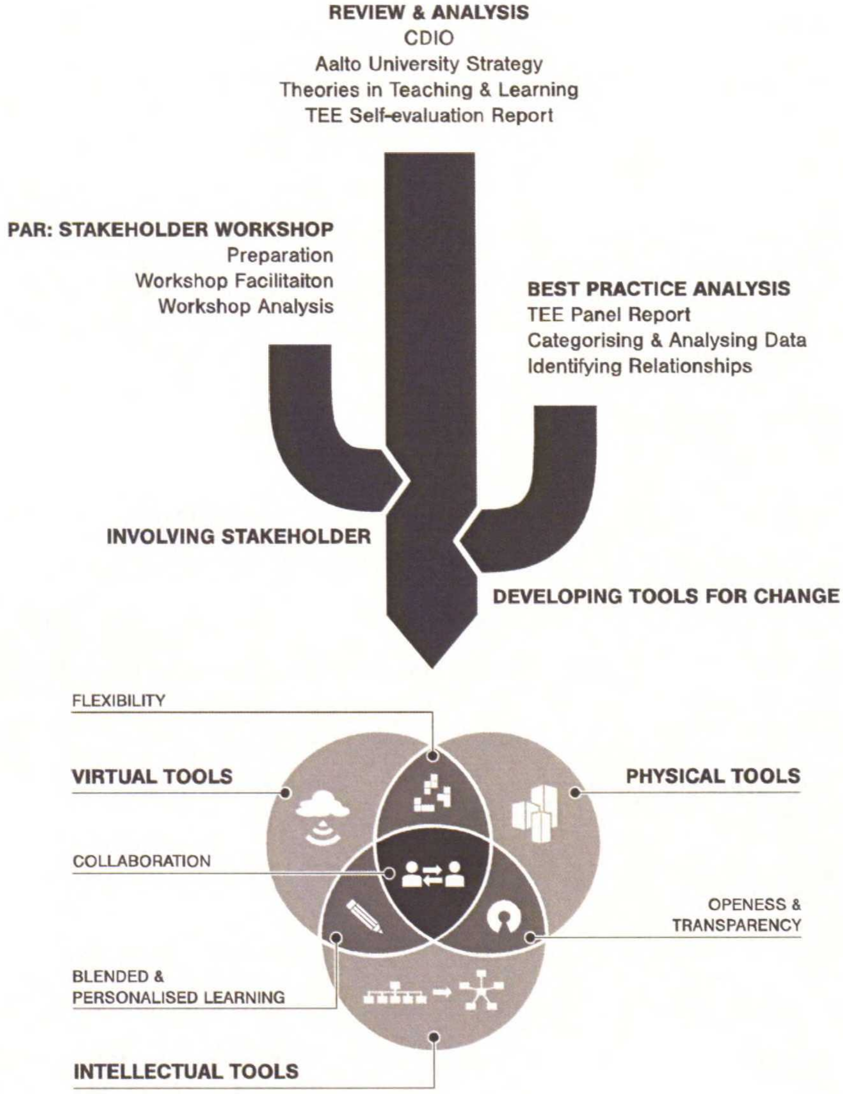

Figure 54 Objectives of the study amounting to three suggested tools

The developed tools are:

- Intellectual tools
    - ICE BRCR (read "ice breaker" for memorability)
    - Black Box Workshop
    - Inverted Classroom
- Virtual Tools
    - Aalto Cloud (Oodi 2.0 + Noppa 2.0)

- Physical Tools
    - Math Gym (and similar concepts)

6.1.1 Intellectual Tools

Intellectual tools are tools that change the ways of working. This tool set consists of the Black Box Workshop, the Inverted Classroom, and the ICE BRCR (read "ice breaker")

ICE BRCR (Ice Breaker)

I believe that the need for producing more scientific knowledge lies in the clever use of students and alumni as resources for research. This tool is for breaking the ice for freshmen, protective students, and alumni or other professionals interested in research or teaching. The name of the tool is developed form creative naming and abbreviation of two courses:

- Introductory Course in Engineering (ICE)
- Basic Reusable Course in Research (BRCER)

ICE and BRCR work as active contact points to the society and industry. As mentioned, alumni may be involved in research projects and be credited for their completion of the course and publications. For Alumni, these credits may be allocated to post graduate studies, depending on their level.

ICE is a course for first year students. It works as an introduction to engineering. In this course, students attend lectures, where on-going BRCR research projects are being presented. At the same time, students work on a light engineering exercise, such as the construction of a pneumatic motor, creation of interactive art, societal development solutions, or entrepreneurial product development. Ideally, the ICE exercise should be interdisciplinary.

BRCR is a reusable course. At the Bachelor's level, students participate as temporary research assistants in projects run by researchers, alumni, or other professionals. As late stage Master's students, graduates, or professionals in the working life, students may retake the course as research project managers and have a small team of BSc-level research assistants. BRCR research projects do not need to be longer than six months (two periods). Figure 55 is a figurative illustration of the ICE BRCR programme.

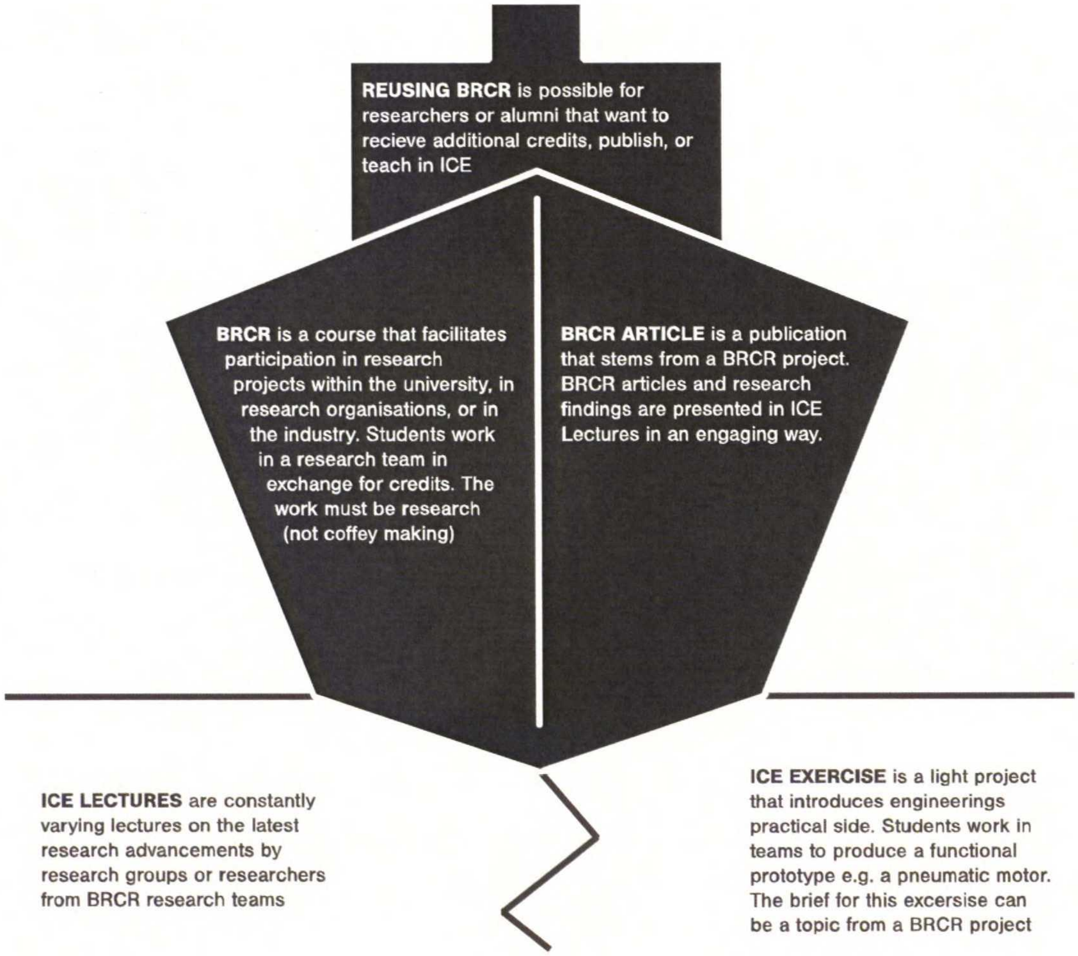

Figure 55 Illustration of the ICE BRCR programme

Simplified versions of the ICE BRCR combination can be offered openly to high school seniors and graduates who are interested in pursuing a higher degree in engineering. It can be offered in its entirety, or as a condensed summer course.

Student and alumni can also be involved in teaching and learning by visiting the Gyms, Clubs, and Study Groups and/or participating via the corresponding online channels that are described in the upcoming sections. For one, this would greatly enforce the strategic goals of lifelong learning, and involvement of the industry and society. Secondly, the participants will self-organise to teach and learn from each other even with unsupervised and unguided access to the virtual learning forums (Mitra, et al., 2001) (Carreras, et al., 2005).

The Black Box Workshop (Bases on Edström's Black Box Exercise)

> *"Teaching units have regular meetings (6-10 per year) to discuss education, research and administrative issues. Units regularly discuss course content, teaching responsibilities, learning outcomes and course feedback. The transition and prerequisites between courses is also reviewed. At least once per year, i.e., before the printing of the study guide, the plan for each course is reviewed in detail. The programme also has a teaching quality group which meets about 10 times per year. Among other issues, this group coordinates teaching and examination schedules." (Aaltonen, et al., 2011)*

The quote above implies that there isn't a forum in place that is solely for refining the curriculums of KoRa's engineering programmes. The Black Box Workshop is a tool that could help to resolve the lack of a session designated for curriculum development. Figure 56 illustrates a concept of how courses could be laid out when planning a curriculum where all courses contribute the programme's learning outcomes directly or indirectly. This concept is, in part, inspired by the STOPS (Paavola, et al., 2011).

The suggestion of a Black Box Workshop is based on K. Edström's "Black Box Exercise" . A Black Box Workshop can facilitate the creation of a learning outcome-based curriculum. (Crawley, et al., 2007)

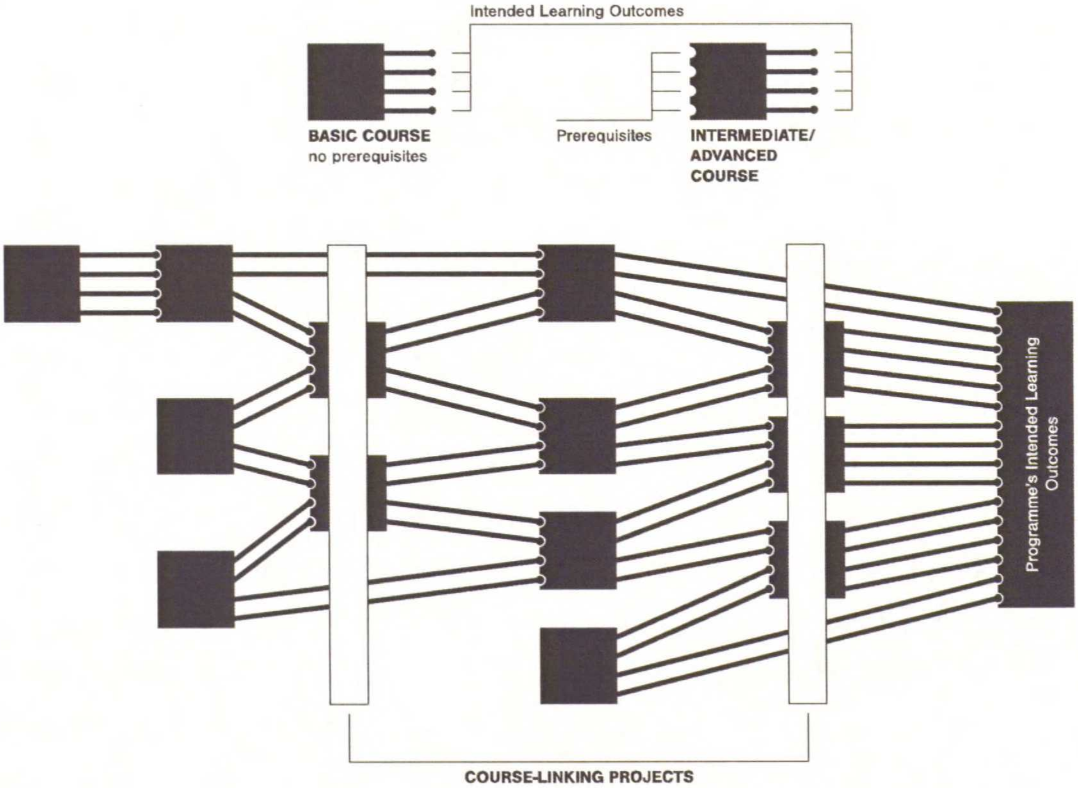

Figure 56 Concept of arranging course learning outcomes to contribute to the programme's learning outcomes. Based on K. Edström's "Black Box Exercise" (Crawley, et al., 2007) and STOPS (Paavola, et al., 2011)

In a Black Box Workshop, the idea is to clarify each courses responsibility in the overall student learning. Faculty prepares for the workshop by creating a short presentation of their respective courses. In their presentation, they state the specific knowledge and skills students should have as they enter the course, and the knowledge and skills they will take with them as they proceed from the course. All the expectations are expressed in terms of intended learning outcomes. (Crawley, et al., 2007)

The Black Box Workshop is different from Edström's exercise in the sense that the short presentations are followed by a workshop where each course is represented by a card and each learning outcome is represented by a piece of string. The courses are places by a timeline on a large table. Workshop participants can walk around the table, modify the curriculum, sketch in details (such as suggestions for courses, exercises, or projects), and discuss. The final result is documented and each participant has an opportunity express their opinion on the derived layout. Involvement of student representatives, industrial partners, and teachers from other departments (such as mathematics, physics, and communication) is advisory.

The Inverted Classroom

The inverted classroom, also talked about as the flipped classroom or the reversed classroom is becoming a recognised way of working. Traditionally, contact teaching, generally takes place between the early morning and the late afternoon. Figure 57 is a representation of the traditional class and the inverted class. The traditional 12 hours has teaching scheduled from approximately 8:00-16:00. In the inverted 12 hours, teaching is pushed to the first and last two hours of the 8:00-16:00 period. In the inverted model, 10:00-14:00 is reserved for guided exercises, group work, independent study, or free time – in that order of importance. The 16:00-20:00 period is reserved for free time, independent study, guest lectures, and group work – in that order of importance. This allows students to flexibly shift free time and study time.

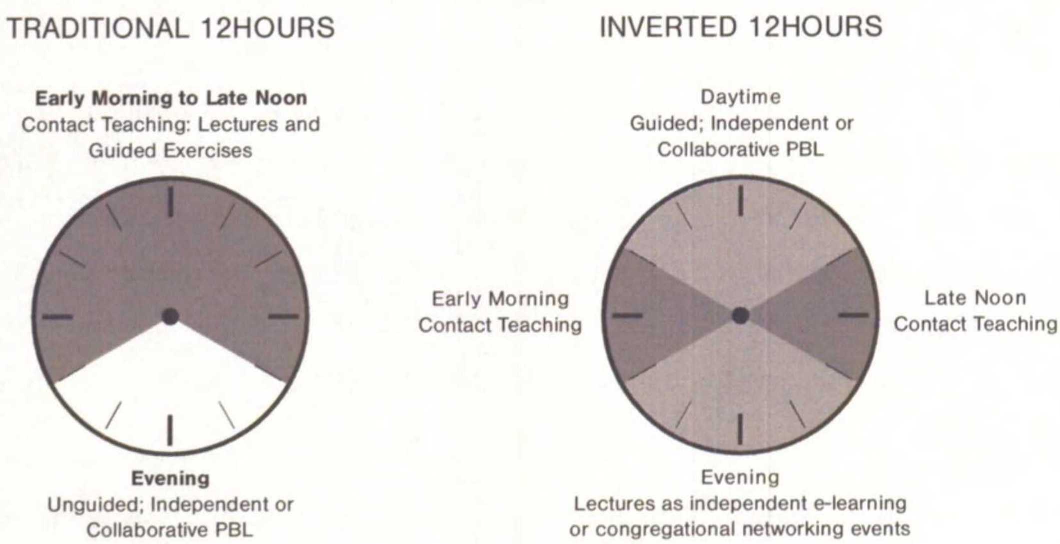

Figure 57 inverted classroom: a recommendation for a new scheduling culture

An existing instance that is a good example of the inverted classroom is the Laskutupa, a space for working on exercises in basic mathematics and physics.

Students can walk in at any given time to work alone or in groups. There are teaching assistant around, each with listed "superpowers" that are fields of specialisation, who are at the disposal of the students. (Raita, 2012)

There are an incredible number of tools that are becoming available for collaborating, exploring, networking and sharing; social media is a growing force, productivity-enhancing tools are becoming increasingly efficient, and people have the ability to create collections of selected information streams that they can interact with by sharing information and joining discussions. These tools are being exploited in the market economy for the competitive advantage that they offer, however the educational practices in KoRa have not yet taken full advantage of these tools in the context of education. Taking these tools into use may require a small team with expertise in media, journalism, web design, and programming. Alternatively, an enthusiastic group of students can drive the development.

6.1.2 Virtual Tools

I believe that e-learning is an enabler for personalised learning on a large scale. This tool is an attempt to contribute to the resolution of the grand challenge of advancing personalised learning. The idea in the suggested tool is that it is and easy-to-use and all-inclusive web service for planning and management of teaching, learning, feedback, research, projects, and anything else that can be easily integrated. The virtual tools suggested are all integrated into a service concept called Aalto Cloud (Oodo 2.0 + Noppa 2.0)[23].

Aalto Cloud (Oodi 2.0 + Noppa 2.0)

This concept is inspires by app stores. Google Play and Apple App Store are services for browsing, buying, and downloading applications. The applications are described briefly, and have a long list of user ratings. The ratings are a driving force behind the development and success of the applications (Sobhany, 2011). Courses can benefit

[23] Oodi and Noppa are names of currently used course management web services

from using student feedback to drive development and as a tool for marketing and decision making by making the quality of a courses public knowledge. Figure 58 is a concept of what could be the landing page for students who have logged in to Aalto Cloud – a concept for a tool that supports and documents lifelong learning.

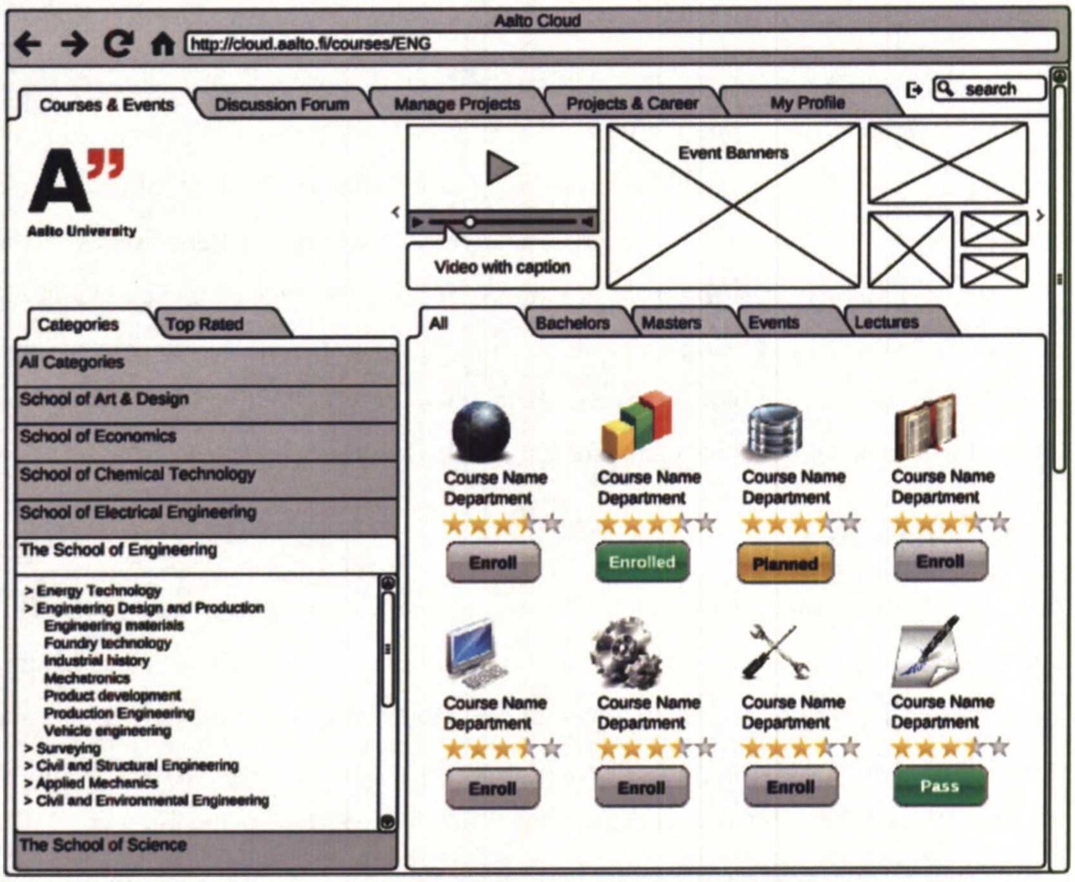

Figure 58 Aalto Cloud - Front Page: Courses and events[24]

Current events, recently published lectures, new assignments, and other urgent information can be displayed in the banner area. Courses appear in small icons, and feedback and quality is made immediately visible in the form of an average student rating. It is central in this concept that feedback is instant, always, visible, and dynamic. Because of that, lacks are pointed out immediately, and good practice can be praised instantly. Courses from all over Aalto are accessible for viewing.

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[24] Icons used in the Aalto Cloud concept are from http://www.freeiconsdownload.com/

Courses are defined by their learning outcomes, content, and ratings. When a student clicks on the link to a course, they get the view in Figure 59. The course content is presented briefly, and it is instantly seen what learning outcomes are required for the course and what learning outcomes are already attained.

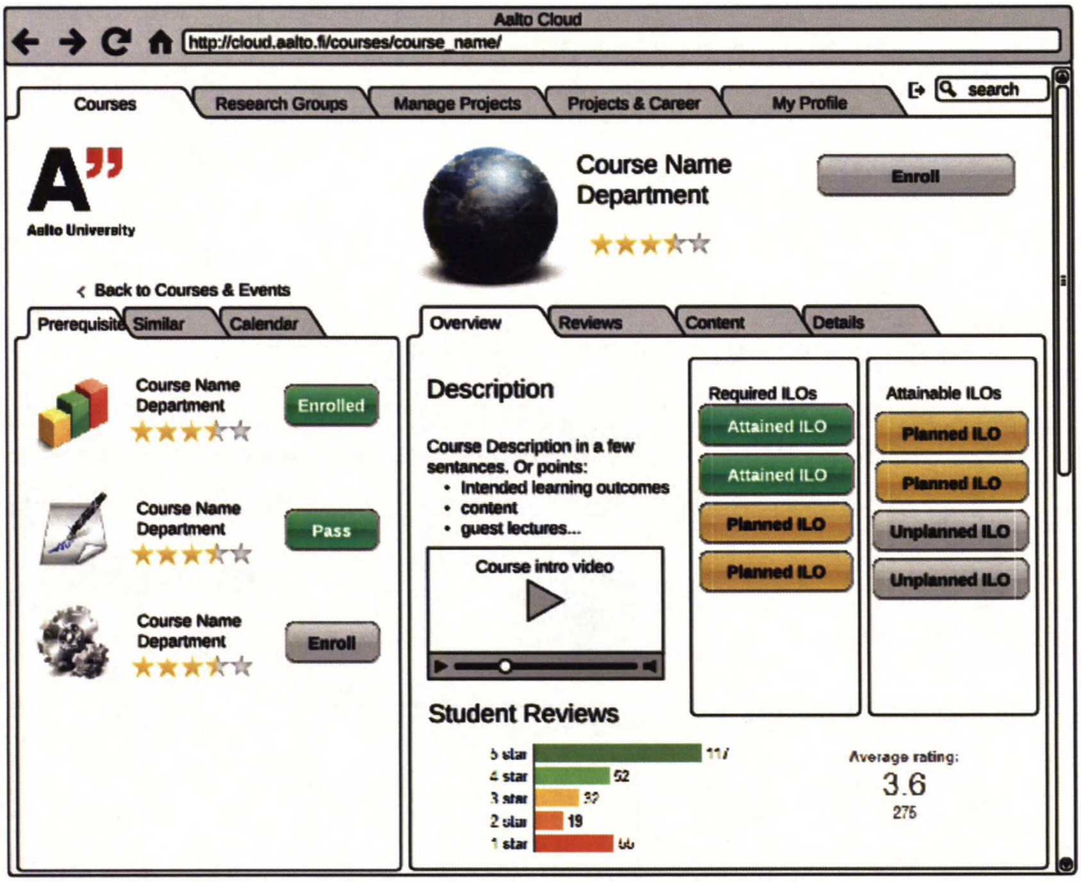

Figure 59 Aalto Cloud - Course Page: Descriptions that focus on learning outcomes and ratings

The learning outcomes in the Figure 59 correspond to a situation where the student has attained part of the required learning outcomes, for a course that is in their study plan. In this example all of the learning outcomes do not contribute to the overall intended learning outcomes. Figure 60 illustrates the example's context in terms of black boxes.

To support blended learning, all the material needed for the conventional courses is online as illustrated in Figure 61. That includes the lectures, and assignments. Any assignment that is not a physical production can be returned electronically. Such a system frees office hours for coaching and guided learning. This supports the inverted classroom.

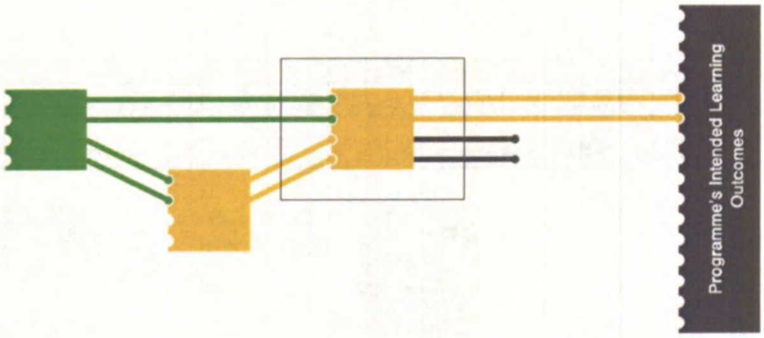

Figure 60 Diagram representation of the course in the example of Figure 60

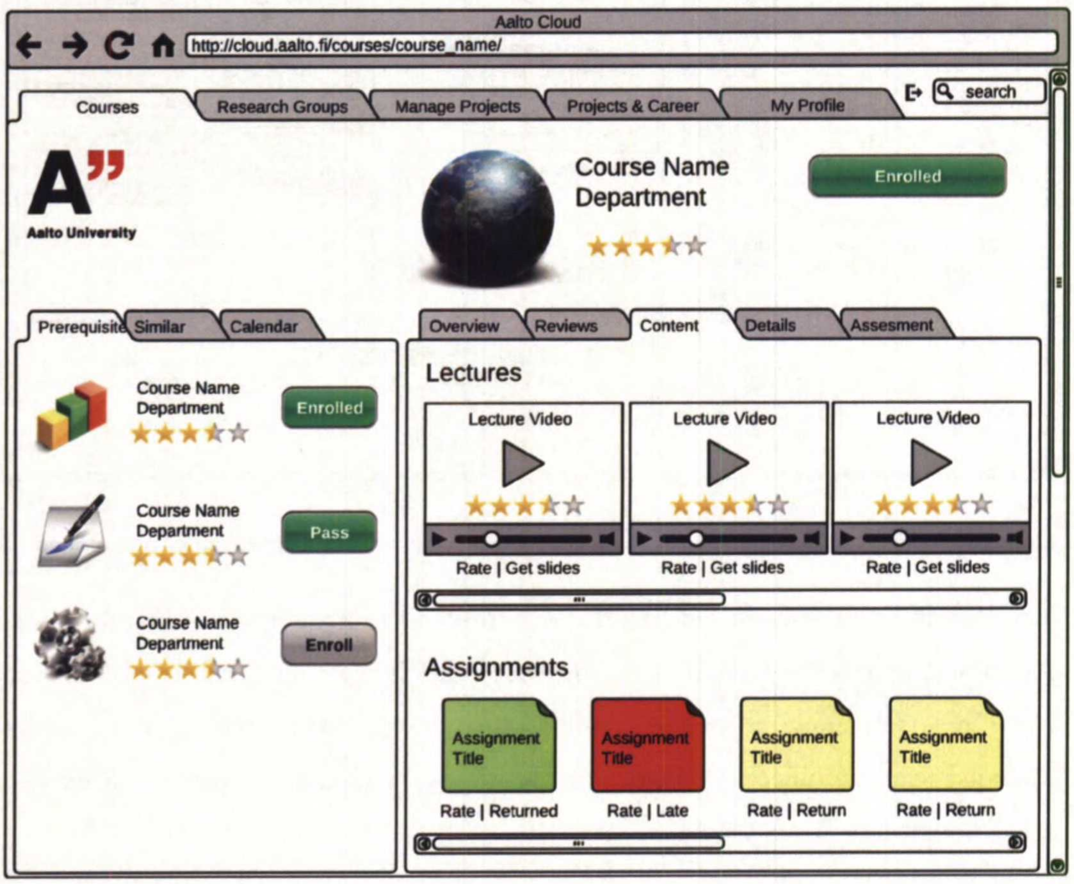

Figure 61 Aalto Cloud - Course Page: E-learning material for a course

Assessment can be done in person and online. Private and public channels can be used within the system to give direct feedback to individuals, groups, or whole classes. Figure 62 is a suggestion of how the online assessment tool can function for a course.

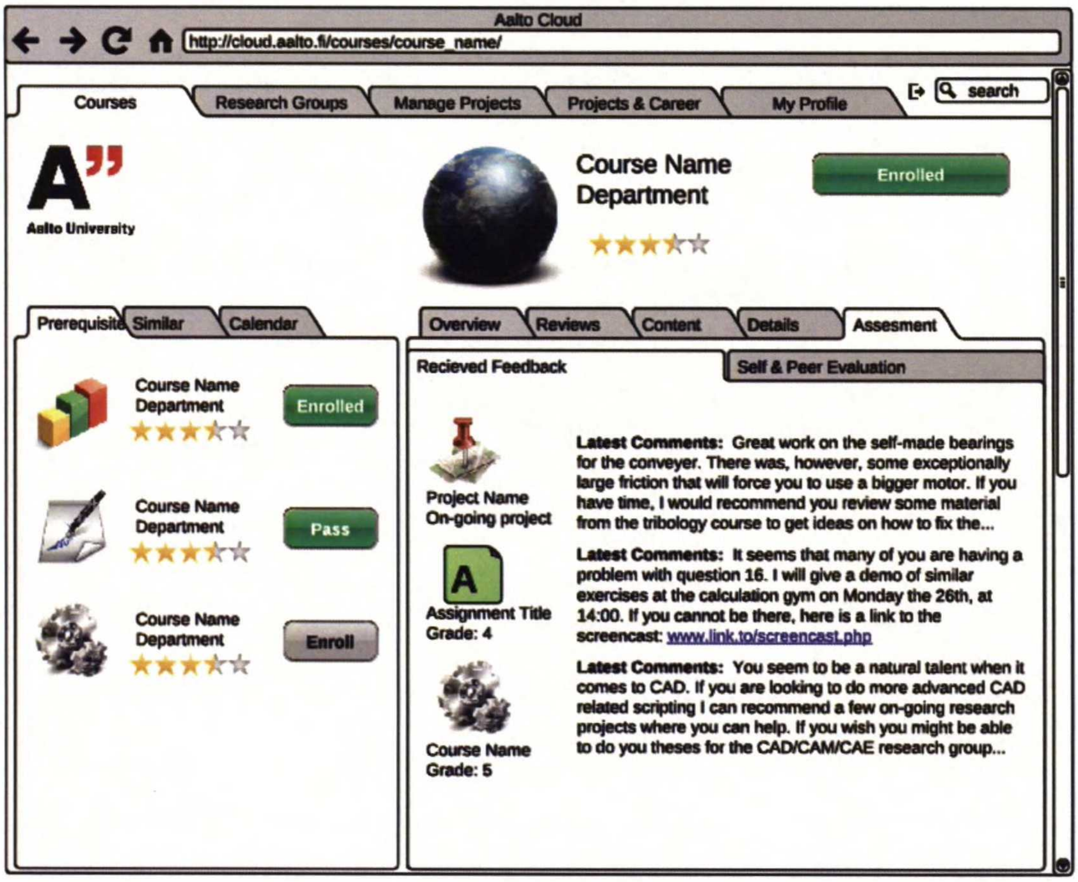

Figure 62 Aalto Cloud - Course Page: Assessment as a part of learning

A lot of the time, feedback is collected so that it is suitable for statistical analysis. In my opinion, the feedback mechanisms are over-engineered. Instead of collecting feedback, which needs processing for statistical analysis before it can be used for decisions, I propose colleting feedback in a way that it is instant, direct to the point, and visible to anyone. Statistically relevant feedback can continue to be collected by individual researchers. Figure 63 is a concept of how the system used for rating everything could work.

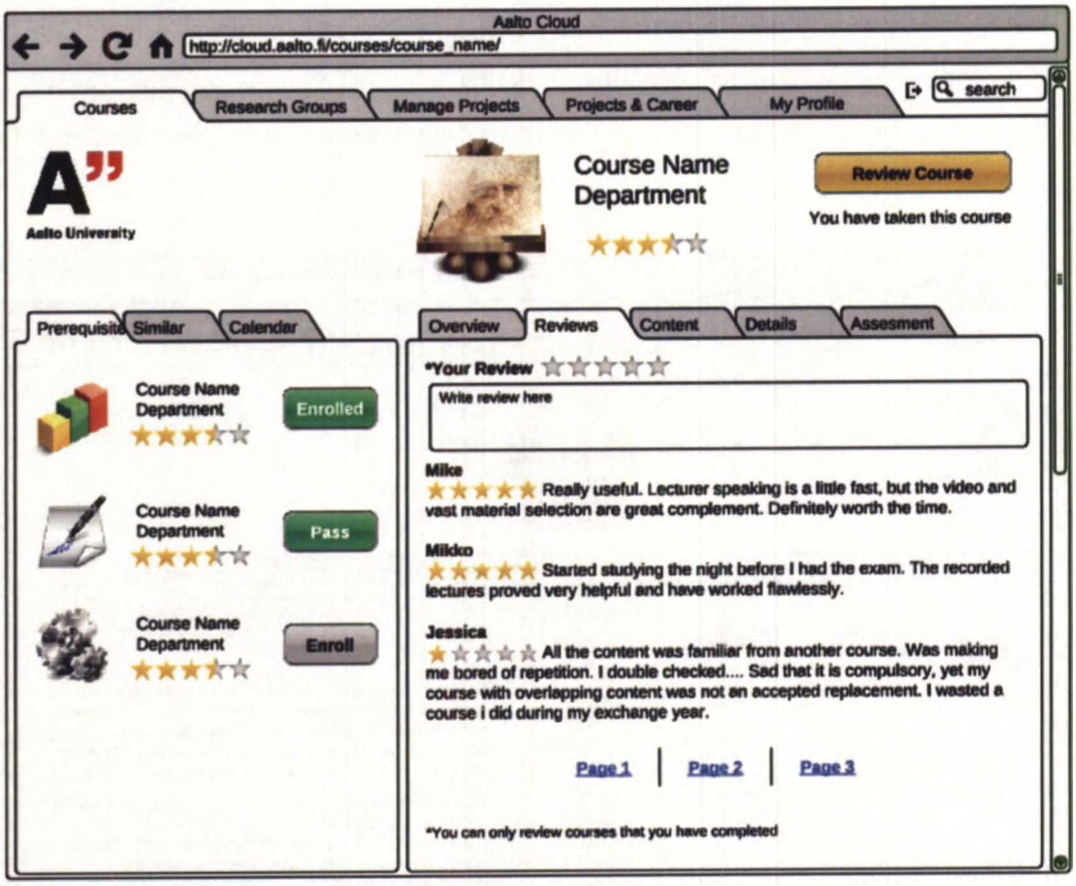

Figure 63 Aalto Cloud - Feedback and Rating Page: Instant, easy, direct, published immediately

The Aalto Cloud system is meant to manage studies and course planning. In the profile page illustrated in Figure 64, a student can see their own profile at a glance and proceeded to planning and managing studies. This tool should be accessible to student even after graduation. It is a way to promote lifelong learning and keep alumni involved.

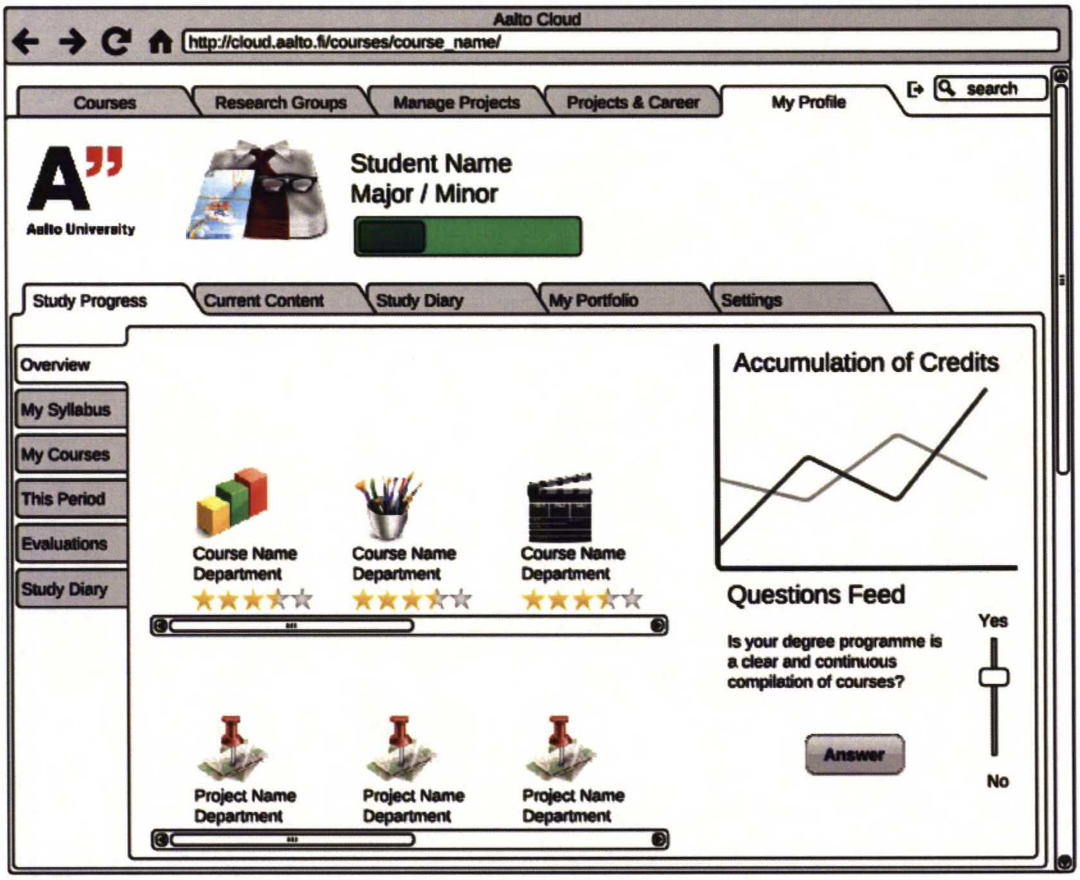

Figure 64 Aalto Cloud - Profile Main Page: study prograss at a glance

To address the need of a programme for programme management for both students and programme administration STOPS (Paavola, et al., 2011) or Black Boxes (Crawley, et al., 2007) can be used as a basis for building an interactive web application for connecting learning outcomes from course to course. Figure 65 is a concept of what the curriculum management interface could be like.

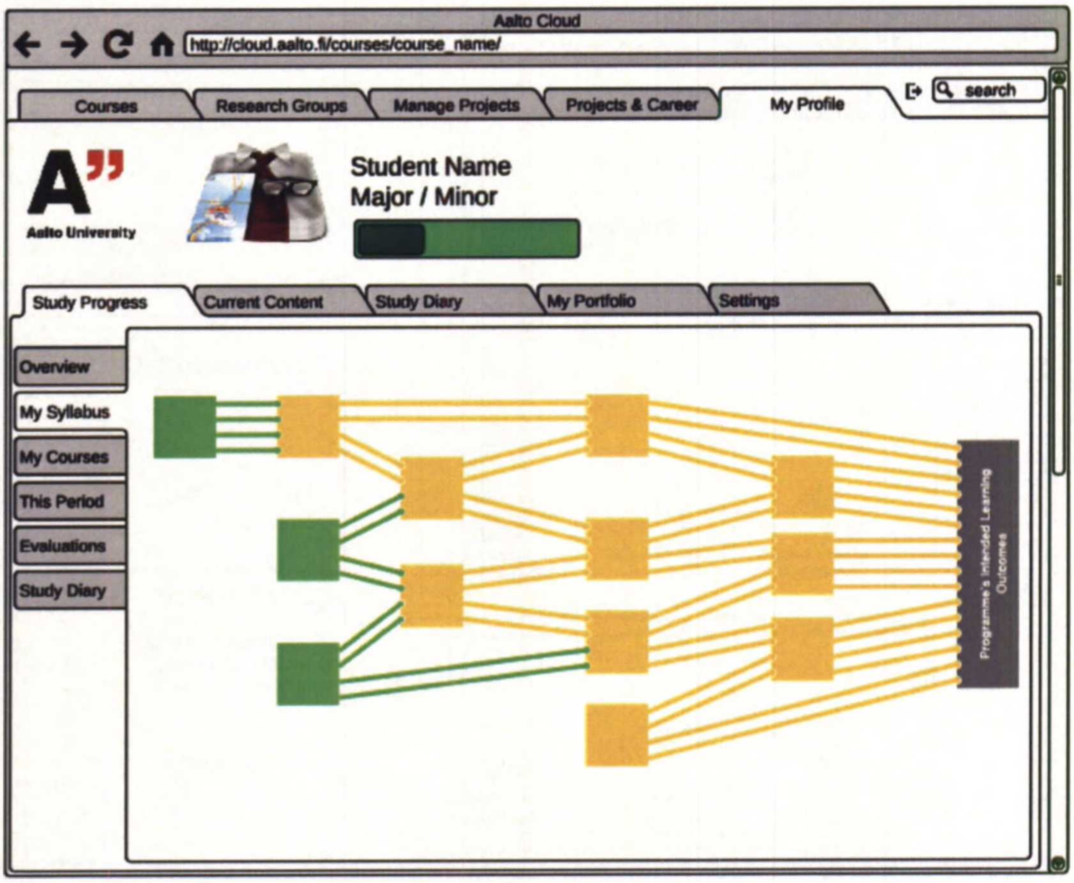

Figure 65 Aalto Cloud - Profile: Syllabus management

Students can start building a project, competition, and job portfolio while they are studying. This service in Aalto Cloud, which is illustrated in Figure 66, is a place where, alumni, faculty, career services, student entrepreneurs, or others, can post relevant opportunities for students to work for pay, or credits with real-world problems, in interdisciplinary teams. Naturally, PDP, IDBM, ME310[25] and other student project courses can recruit students through this channel.

[25] PDP, IDBM, and ME310 are existing interdisciplinary student project courses that are done in collaboration with companies

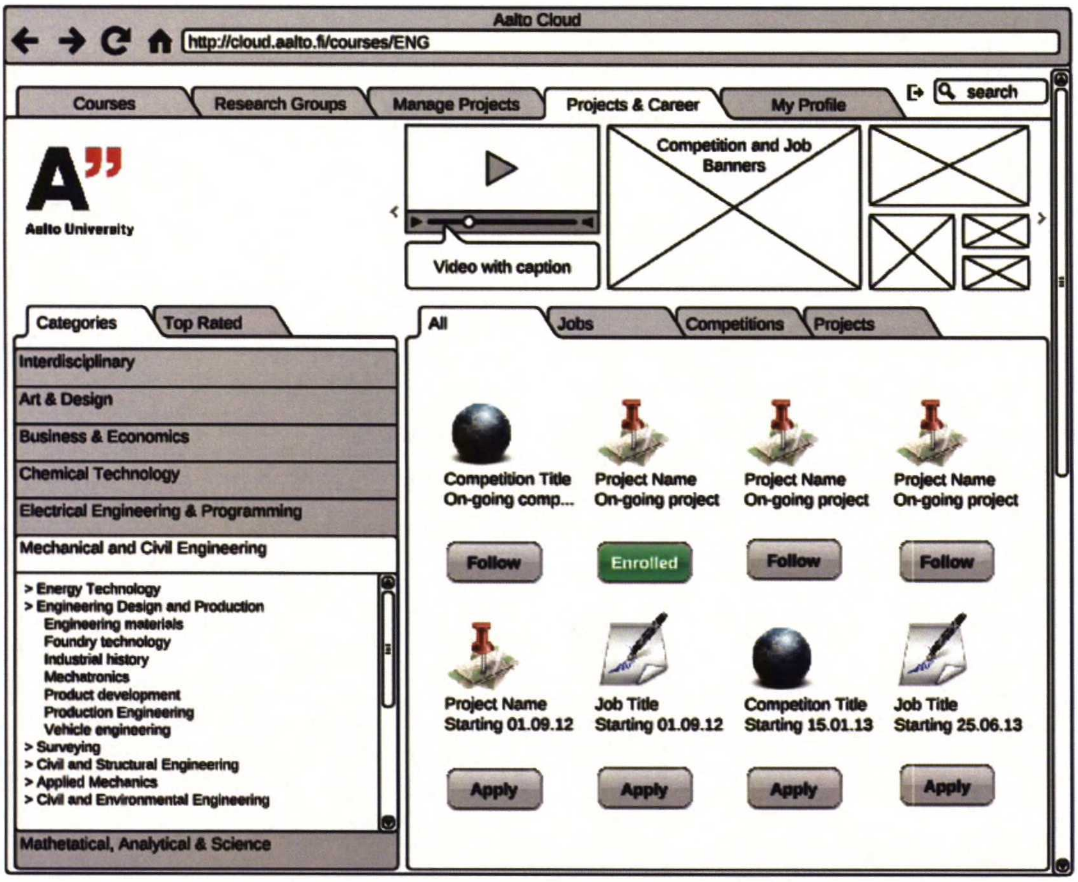

Figure 66 Aalto Cloud – Project & Career Page: interdisciplinary projects, competitions and jobs

Inspired by the Best Practice Cards (Appendix B), Figure 67 is a concept of a section in Aalto Cloud where teaching practices can be shared and developed. Whether or not students have access to participate, in the sharing of teaching practices, is open for discussion.

> *"Since the number of courses offered in the university is large and the development of the course content is distributed to different schools and spread to individual professor level, it is challenging to administrate the whole course program in detailed content level. The only foreseeable solution for this is the streamlined internet based program development process and active discussion among course providers in advance about planned refinements and new openings for courses." (Aaltonen, et al., 2011)*

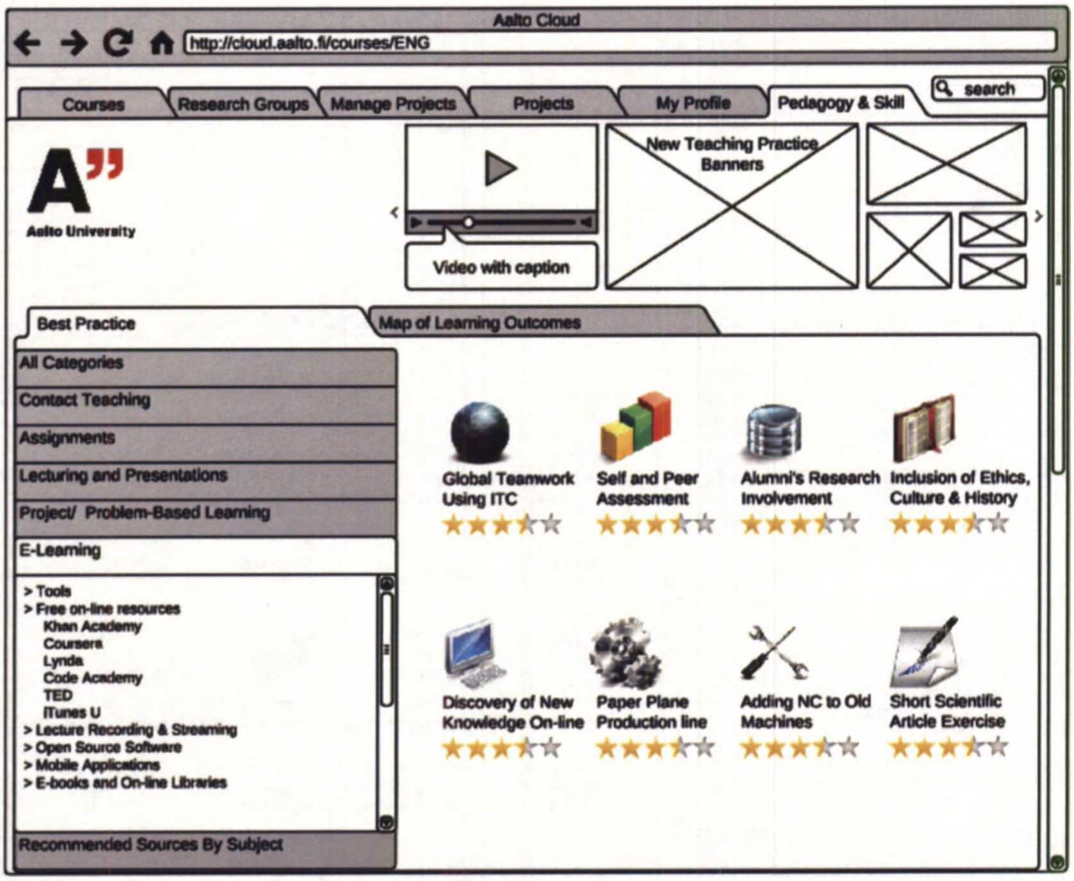

Figure 67 Aalto Cloud – Pedagogy & Skill front Page

The previous quote implies that a system for managing the large space of courses and learning outcomes is needed. The service for mapping and managing learning outcomes creates with all the learning outcomes as stars. The system, which is represented by Figure 68, is intuitive, searchable and filterable.

To support blended learning and flexibility, these virtual tools need to be combined with the intellectual tools and the physical tools.

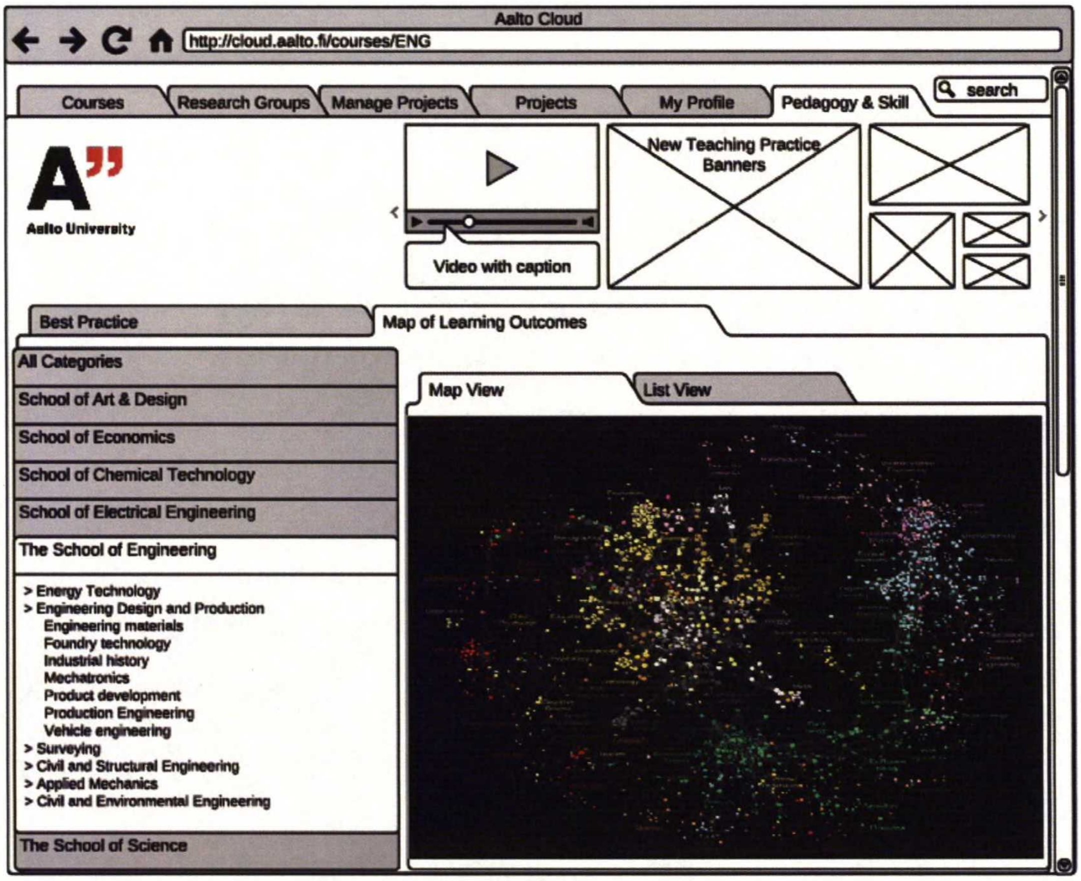

Figure 68 Aalto Cloud - Learning Outcome Map: a system for managing all the learning outcomes and connecting the dots in the curriculum

6.1.3 Physical Tools

In this context, physical tool are infrastructure, events, or procedures that bring people together or facilitate a hands-on approach. The Design Factory has been a perfect example and source of inspiration when it comes to building co-creation spaces. A great deal of what is conceived, designed, implemented and operated in the design factory is done in the spirit of co-creation by the people who actively use Design Factory. Recently there have been a few Design Factory inspired spatial changes within KoRa's main building (Aalto Design Factory - We Inspire, 2012) (Gryada, 2012) (Kalska, 2012). Currently, there is an appropriate momentum to build on those initiatives.

Study Groups, Gyms, and Clubs

- Math Gym & Physics Gym
- Language Clubs
- Scientific Writing Gym

This suggestion will focus on the Math and Physics Gym, which is essentially an upgrade of the Laskutupa (Raita, 2012). Language Clubs would be more organised around cultural activity, excursions, and alumni trips. A home base all Language Clubs can be centred at Aalto's Language Centre. The language centre can be encouraged to be more appealing by adding a movie theatre for foreign movies, and international film festival re-runs. Language Clubs could have the role of being cultural organisations around language. Physically, the Scientific Writing Gym could be a similar to the Math & Physics Gym (Figure 69), the main differences being the topic.

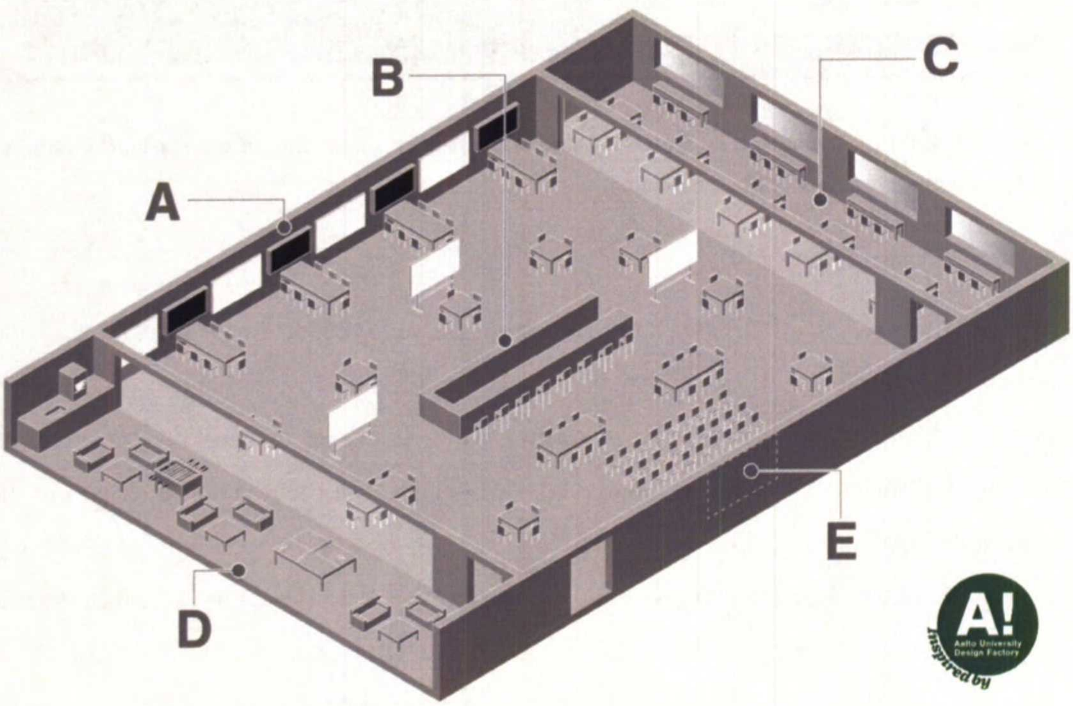

Figure 69 Math & Physics Gym: An upgrade of Laskutupa A) Group Work / Tutoring Areas; B) TA's Helpdesk; C) Silent Workspace; D) Relaxation Area; E) Digital Whiteboard / Lecture Space

Also, it might be more convenient to have the silent workspace occupy a slightly larger portion of the space, in the case of the Scientific Writhing Gym. Scientific writing should be introduced earlier in the studies. It is a skill than needs to be practiced and is commonly one of the overwhelming components of thesis writing. The Gyms are places for exercising logic, mathematics, and scientific reasoning.

Computers are not being used to their full potential in basic mathematics. Therefore, the computer as a mathematical tool can be embraced by doing exercises with modern mathematical software, the tutoring / group work areas (A) can facilitate good instruction is such exercises (Figure 70).

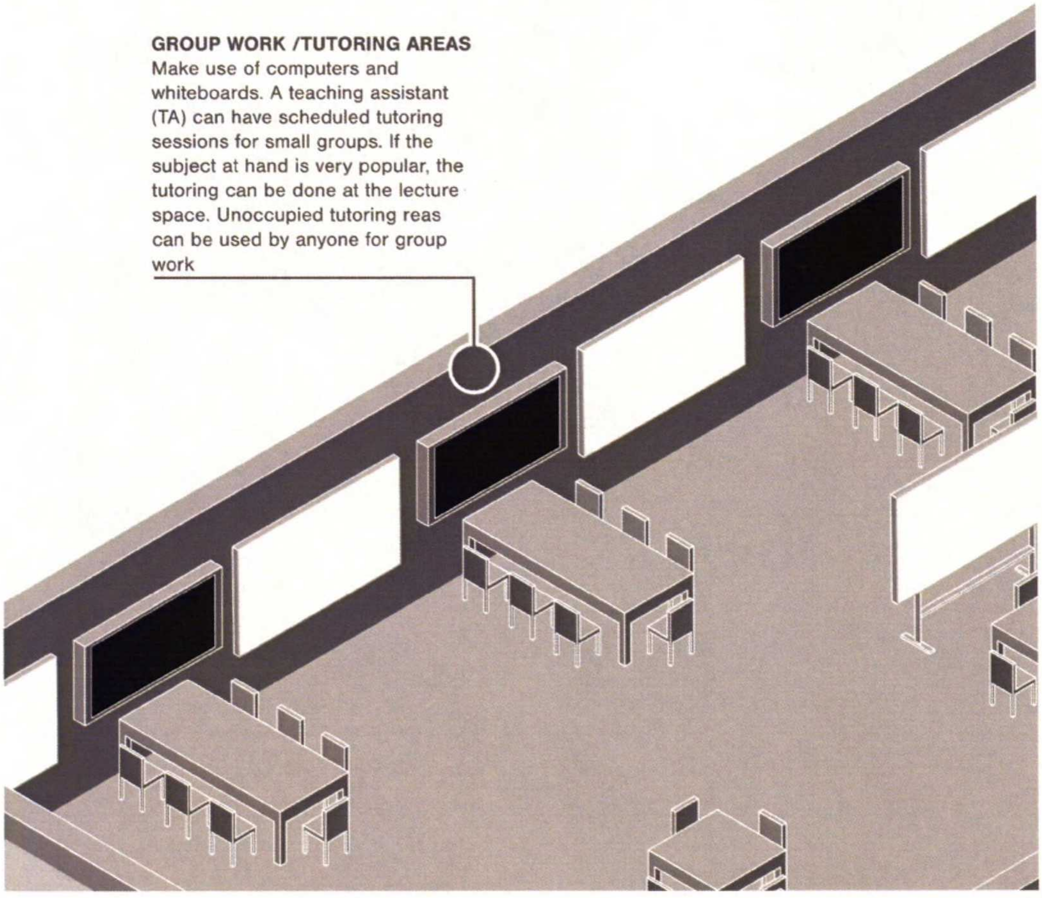

Figure 70 Math & Physics Gym - Group Work / Tutoring Areas

The TAs (Teaching Assistants) have a space where they can work while being fully accessible. The TA Helpdesk (B) is a centrepiece of the Gym.

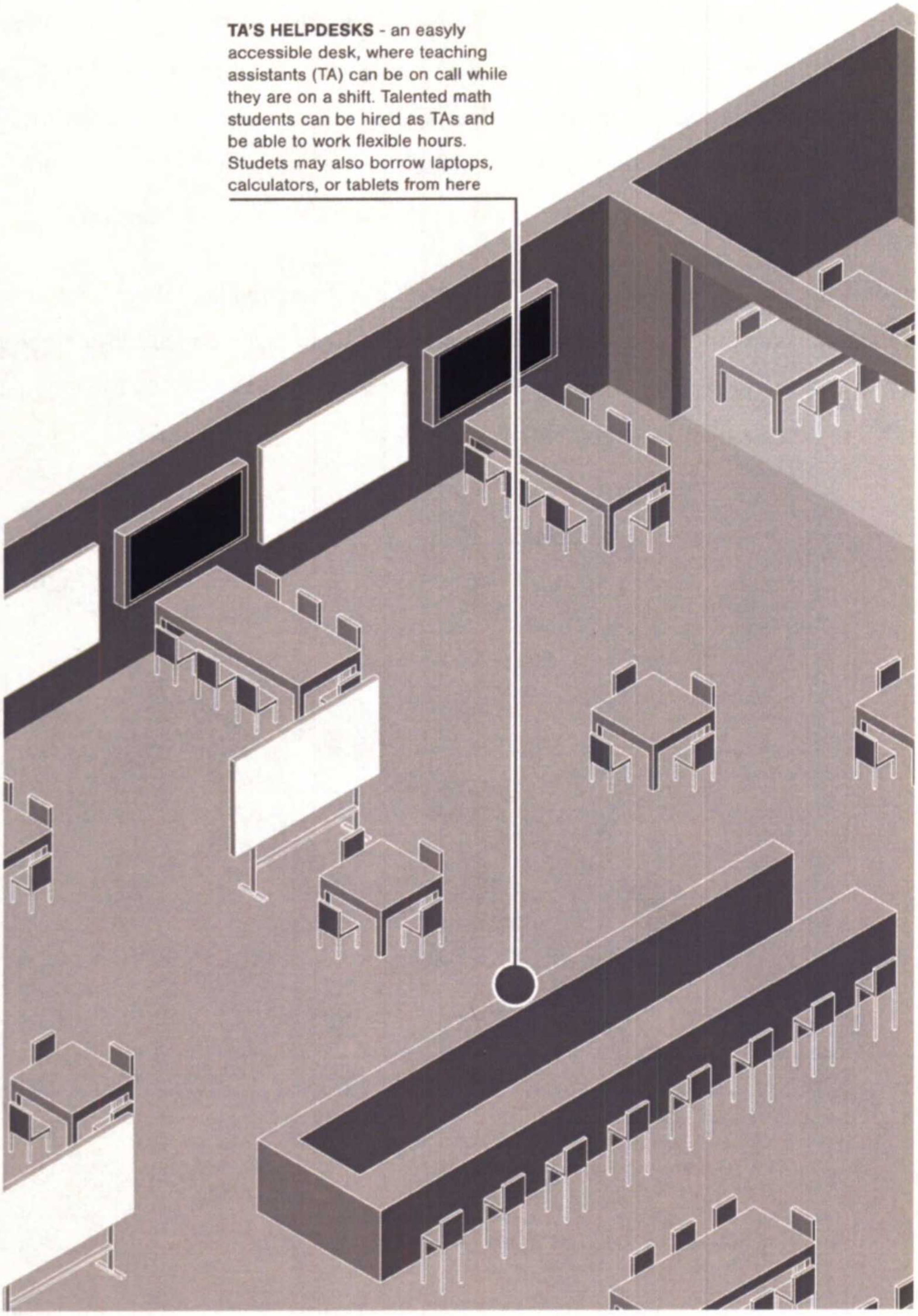

Figure 71 Math & Physics Gym - TA's Helpdesk

Some people need silence to concentrate, but may still want to work in a place where help in near. For that reason, the Gym has a silent workspace (C), which can also work as an exam room for retakes of exams (Figure 72). The whole space is transparent, so if working on an exam, the TAs can supervise the silent workspace from behind their desk

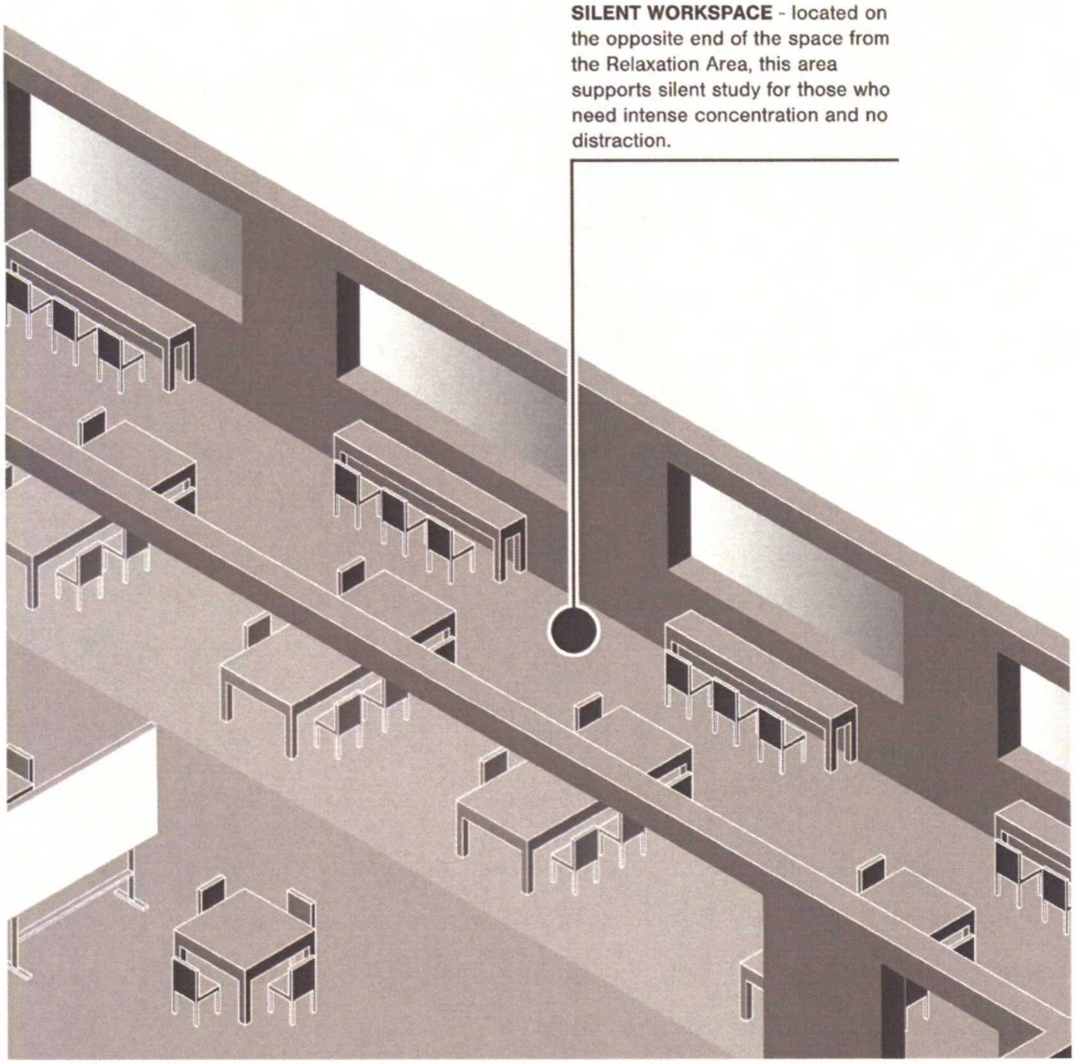

Figure 72 Math & Physics Gym - Silent Work Space

The brain needs the occasional break from thinking. Getting physically active, drinking coffee, reading magazines, or having a relaxing chat can help students enjoy their time at the Math Gym, and have the resilience to keep working on the challenging exercises. The relaxation area (D) is included in the concept to serve these needs (Figure 73).

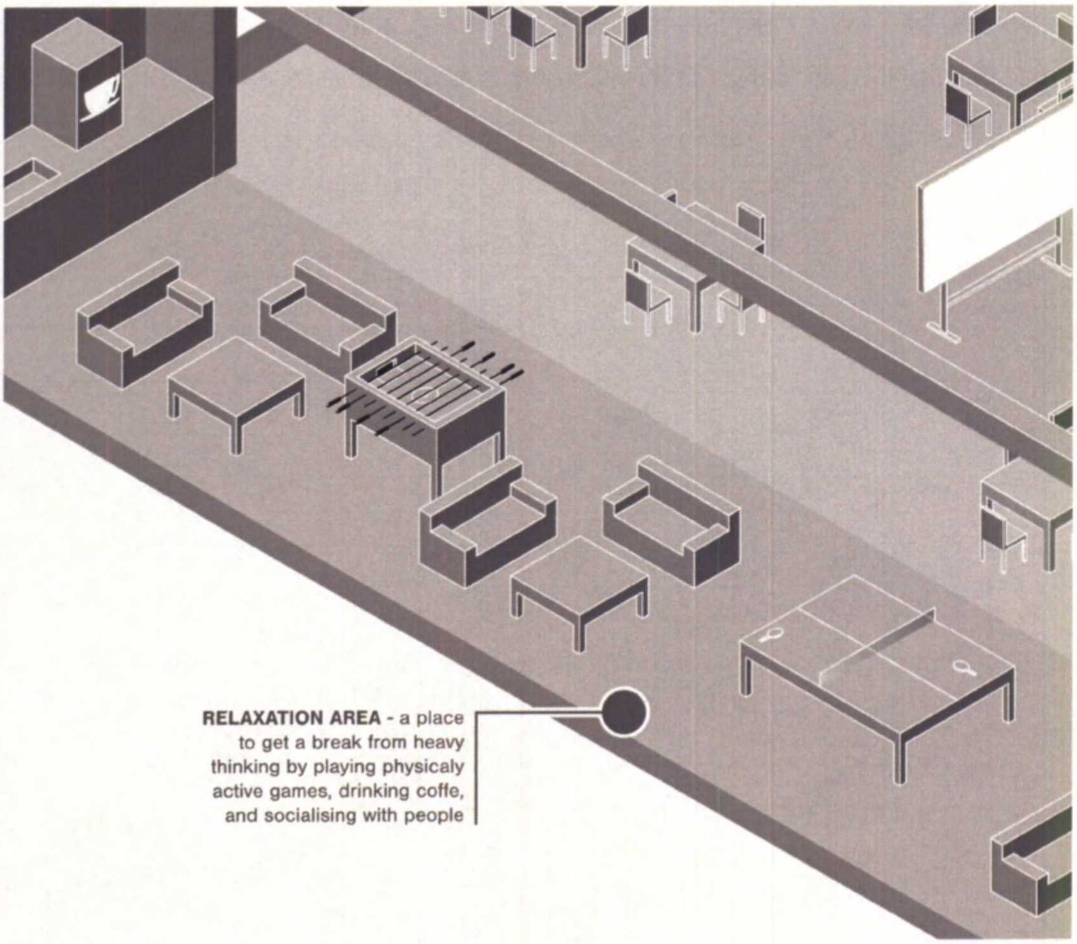

Figure 73 Math & Physics Gym - Relaxation Area

This concept is designed around the hope that traditional math and physics lectures for fundamentals will be replaced by short recorded lectures. However, occasionally there might be a need to present new finding, inspiring applications, or corrections of common misconceptions to a larger audience. For that reson, this concept includes a small lecture area (E), which can be used flexibly for demos or lecture recording in front of an audience (Figure 74). The lecture space is equipped with a digital whiteboard that supports the use of demo software such as MatLab, Mathematica, Processing, or Algodoo.

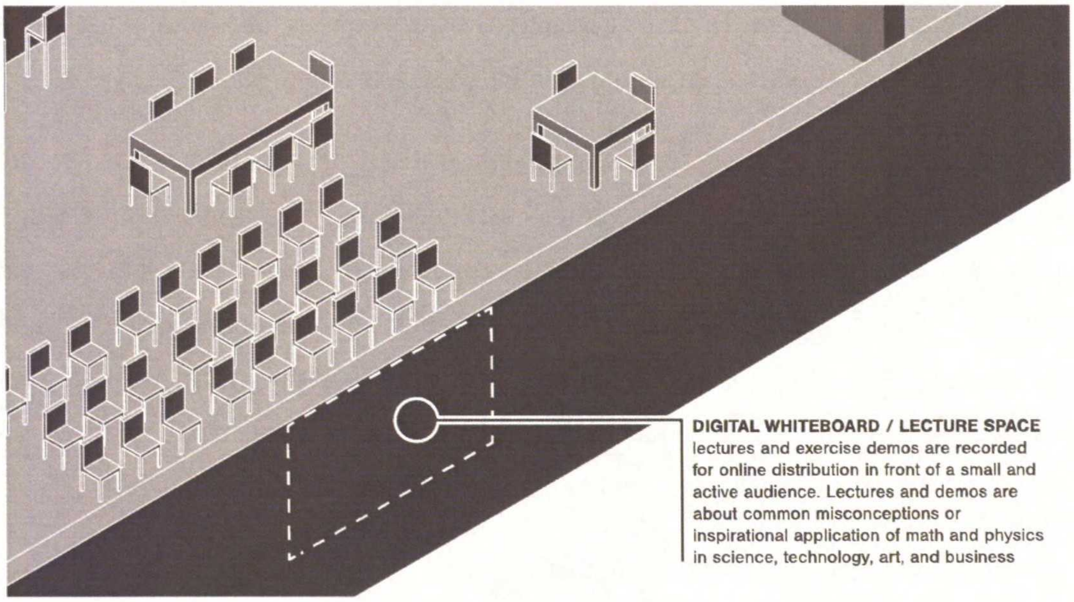

Figure 74 Math & Physics Gym - Lecture Space / Digital Whiteboard

All the Study Groups, Gyms, and Clubs should have associated online resources and communities. For instance, mathematics can be supported by online video, such as those of Khan Academy. The idea of outsourcing mathematics and physics is derived from the results of Group 6 from the workshop. The victual tools are discussed in depth in the previous section.

6.2 Using the Tools

The combined use of all the tools can result in remarkable advancements in KoRa's engineering programmes. The virtual and physical tools may need Aalto-level resources and collaboration; nonetheless, KoRa can initiate the action by providing the first high quality Coursera course, prototyping virtual education management tools, and continuing to develop educational spaces (lecture rooms being the next target).

6.2.1 Virtual Tools that are Developed by the Users

There is need for a new internet-based curriculum development tool for administrating the wide and fractured course spectrum. A lot of information is already attainable on the current database system; however, there are no working tools that can be seamlessly used for curriculum development. (Aaltonen, et al., 2011)

The need for an adaptive, functional, and efficient ICT tool can be met by empowering the users with a tool that they can tweak, improve, and optimise within their abilities. Most users can be able to contribute by reporting problems and creating content, experienced users can contribute by recording macros [26] and reorganising the user interface for optimal workflows, and programmers/developers can create applications and widgets[27] that can be integrated into mobile devices, e-mail clients, electronic calendars, and interactive info screens terminals.

There are a variety of virtual tools that are used to perform functions, which are essentially finding data and submitting data. For the information systems being used to be as flexible as possible and develop gradually, developers need to be offered building blocks, such as APIs[28], that enables them to test and develop customises systems that can be offered to the generic user, or optimised for specialised workflows.

When it comes to adopting the latest technology in teaching, the limiting factors are resistance to change, and the steep learning curve associated new technology. Both of these obstacles can be overcome if there is a sufficient investment in the integration of new technologies into the current teaching practices. Furthermore, accessible guidance, and construction of intuitive user interfaces is necessary for successful adoption of new technologies.

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[26] Automated and recordable series of actions within an application

[27] Essentially, easily attainable add-ons or applications within application

[28] An application programming interface (API) is a catalogue of specifications that is published for a software application. By using API's, which are usually openly accessible, different software can easily be programmed to interact with one another.

6.2.2 A Reformed BSc Programme

When redesigning the programme there are a few assumptions, which are embedded in engineering education culture, that need to be broken:

- Offering the same course content to multiple students is the only efficient way to make use of the resources available
- Students should be taught only what is known
- Fundamental studies cannot have varied content

The idea is not to graduate generic engineers, but skilled people who are passionate about what they do well. Instead of equipping students with the same set of tools, they should be guided in independently exploring and obtaining the right tools for the job; fundamentals should truly support the ILOs.

In Figure 75, a model curriculum is made so that it builds on previous knowledge and used some best practices from CDIO. It is partially based on the bachelor degree reform (Kuuva, 2012).

The essential points for this curriculum suggestion are:

- Computer Sciences include programming, electronics and micro controllers
- BRCR (Basic Reusable Course in Research) A real scientific research project is included early in the study (constituted by the tool presented in Section 6.1.1)
    - Courses on using the computer as a tool (Excel, Word, Matlab, Reference management tools...) are outsourced to online teaching, and the facilitation of a study group for using the computer as a research tool. Using the computer as a tool is integrated into the research project
    - The course can be taken a repeated number of times

    - Alumni has free access to the course, on the condition that they contribute to or lead research, and are prepared to share new knowledge by teaching in the introductory engineering course
- Mathematics becomes more continuous and is stretched out throughout the degree. The continuity if mathematics is a best practice that is inspired by the CDIO activity at Tampere Technical University
    - An intensive 10cr of math in the beginning (only the very essentials)
    - 10cr of math are spread out as continuous exercises that span the remainder of the degree and are assigned by teachers of disciplinary courses
    - Math classes are given online
    - There is a designated place for exercising math and physics (Math & Physics Gym, Section 6.1.3)
- CAD is a central tool for mechanical engineering
    - CAD should be taught early and practices continuously
    - Early CAD provides an introductory experience to engineering
- ICE There should be a contemporary course that introduces the engineering experience (Crawley, et al., 2007).
    - Has a slot reserved for the duration of the first year
    - Has variable content: the latest advancements in mechanical engineering
    - Is closely related to the research project
    - Suggestions for the current theme/topic of the ICE:
        - *New Production Technologies & Advancements in Material Science*
        - *Mechanical Engineering in the Age of Information and Bionics*
        - *Participatory Engineering in Global Teams: Multidisciplinary Design with Users and Society*

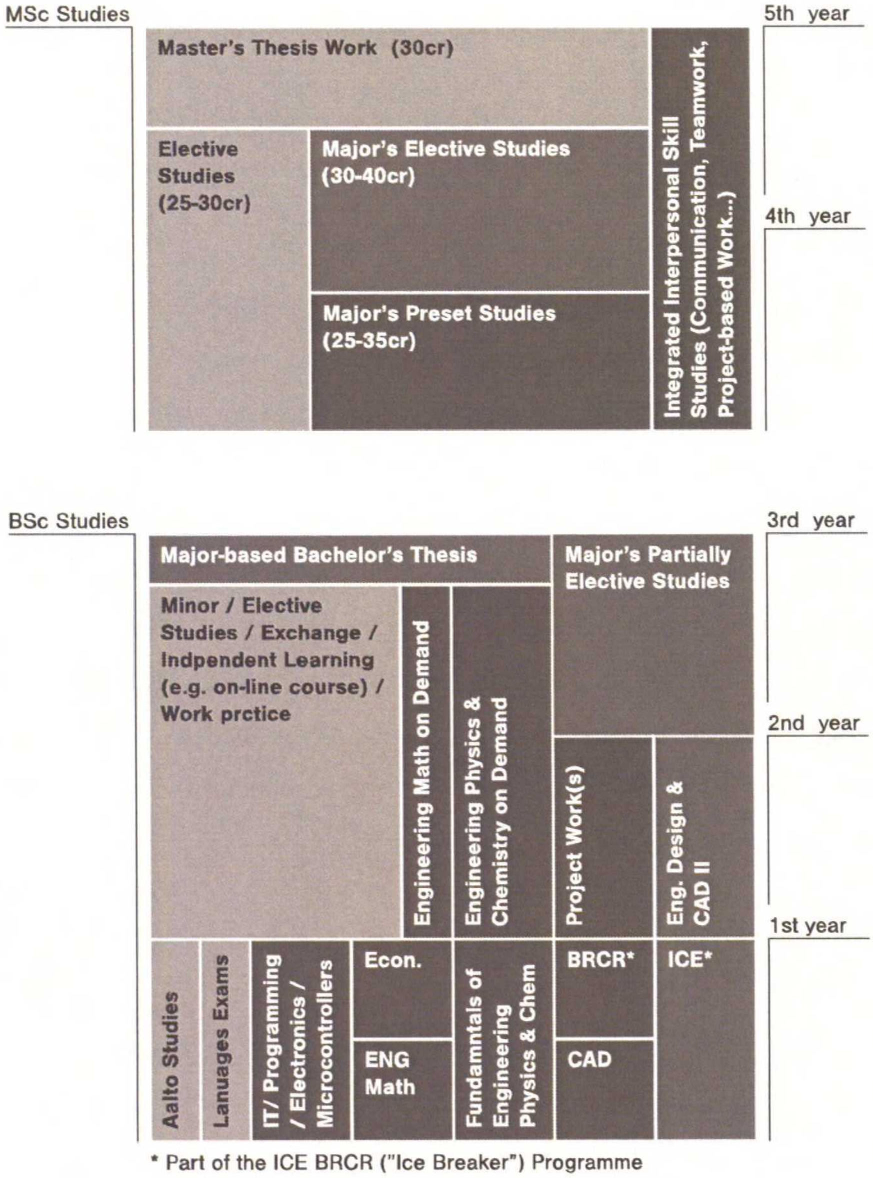

Figure 75 Suggestions for a curriculum structure

A curriculum based on the continuity of learning outcomes, not prerequisite courses, would be ideal. The reasons for this are:

- Students can streamline their studies by studying exactly what they need to achieve specific learning outcomes
- For students who want to take a minor with many prerequisites, learning can be streamlined so that less of the elective study quotas is used on prerequisites

The requirements for putting this into place would be:

- Courses are planned so that they can give variable credits
- An intuitive and reliable system for managing student registration and activity, learning objectives, and credits

Knowledge gaps occur when there are inexistent or insufficient links between content of consecutive courses. The counterparts of a knowledge gaps are excessive overlaps, which are common symptoms to lack of concurrent planning of the degree programmes. Clever use of tools for curriculum design can be used to overcome the gaps. The Black Box Workshop is an ideal tool for such planning. Also, the spiral curriculum, which is introduced in the literature review (Figure 30 on page 57), can be a powerful tool for curriculum planning. The spiral curriculum and the accompanying example (Table 2 on page 58) that are introduced in Section 3.3.1, is an example of how constructivism can be better applied in KoRa's engineering programmes. It can be used to sketch out a programme and its learning objectives in preparation of a Black Box Workshop.

7 Conclusion

I believe that the easiest and most reliable way to evaluate the suitability of best practices, and the developed tools, is to try them. This work is an iteration of educational development that would be good to repeat in order to maintain comparability and monitor development.

To conclude, a brief summary of this work will recollect the significant points of this study. Note that the suggestions and recommendations deduced are based on available facts and observations; therefore, there is a qualitative margin of error for the presented results. There appear to be many points of view on the direction that engineering education should take in the future. It is seems to be that there are no right or wrong directions. This study has brought me to understand that some of the goals and values of engineering education are rightfully subjected to opinion in the same way that personal opinions and political values are. Accordingly, best practices in engineering education are also matters of opinion – to a reasonable extent.

In summary, the most significant changes that can be made to improve engineering education in KoRa are:

- Become learning-centred
    - From talk about prerequisites to planning learning outcomes
    - From teaching to coaching
- Increased collaboration
- Application of modern educational tools
- Acknowledgement of students and alumni as resources
    - For teaching
    - For research

Educationally, KoRa has a lot of great things to offer and is, in my experience, already a world-class programme.

To remain a world-class programme and to continue to improve, KoRa needs to:

- Adopt a culture of constant development and change
- Establish tools and practices for clear communication and management of change

This study set out to inspire a constant cycle of development of teaching at KoRa. This implies that the initial belief has been that development in KoRa was not fast-paced. However, over the duration of this study, a lot of change has taken place and proven otherwise. Teaching in KoRa is not being done wrong. Most, if not all, of the practice in use are relevant to specific real-world demands. However, because of the increasing uncertainty of the future, tending to specific demands is not enough. Furthermore, there is a constant need to improve the efficiency of the educational programmes in order to keep up with the pace of technological development and environmental change, and to do so by making use of the available resources. In other words, despite the continuous development of education at KoRa, keeping up with the speed of technological development will require faster development cycles and eventually a flexible and quickly adapting curriculum. The key to improving efficiency and flexibility is collaboration.

The future is becoming more and more unpredictable. To face an uncertain future, teaching needs to be flexible. Flexibility in curricula is supported by openness and the freedom to create custom combinations of courses. Openness and freedom of movement between courses requires that the faculty collaborates seamlessly within the department, within Aalto and with external partners.

7.1 Strategic Implication of Results

Aalto is repositioning itself as a producer of knowledge (Aalto University Strategy, 2011). With the growing number of institutions that offer degrees, universities worldwide are differentiating themselves from the other degree providers by being, first and foremost, producer of knowledge. To emphasise on points made, I believe that putting this strategy into play requires that universities collaborate, adopt a learner-centred attitude, take command of modern teaching and learning tools, and use students and alumni are resources in teaching and research. The suggested tools are ways of enforcing these four essential goals.

"Animals endowed with the social instincts take pleasure in each other's company, warn each other of danger, defend and aid each other in many ways. These instincts are not extended to all the individuals of the species, but only to those of the same community. As they are highly beneficial to the species, they have in all probability been acquired through natural selection."

-Charles Darwin

Collaboration is essential for universities to face the future. The reach of excellent teachers is growing, so much so, that students are KoRa will be looking to take free online courses from professors in Stanford, Cambridge, MIT, and other world-class universities. I believe that the future of university education is in the building of collaborative networks that, together, offer the full coverage of a disciplinary field with top-quality, interactive, and engaging online teaching. The teaching content is to be produced by faculty within the network with each teacher contributing taking the time to perfect the lessons that they are most skilled in teaching. An important factor for this equation would be that teachers spend their office time being guides for the students who consume the interactive online content. I believe that free online education is a disruptive force that will push universities to collaborate in order to survive. This is a belief that is shared (Vest, 2010) (Christensen, et al., 2008).

Other suggestions in this study can only complement the benefits of collaboration. Collaboration can have a positive effect even when it is extending between disciplines that may appear to have nothing in common. Constant formation and reformation of collaborative relationships is necessary to meet the unknown and continuously emerging real-world demands. Multidisciplinary collaboration promotes divergent thinking, which is necessary for the uncertain and challenging future.

Students and alumni should be recognised as resources. This call for

- A system that support creation and distribution of learning material, mass communication, and crowdsourcing
- A way to incentivise lifelong learning and research publications

In accordance to the Aalto strategy, I believe that the suggested virtual platform concept should be used in the development of virtual support services. When designing the service, attitude should be that anything is possible to implement. People have a tendency of implementing functions that they know are possible, rather than trying to implement functions that are needed. In today's world the boundaries of reality are approaching our imagination. The starting point, of implementing a virtual support service that supports Aalto's strategic goals, should be a concept of the best imaginable virtual support service. In the case of such a concept, best could be defined as user-friendly, effortless, flexible, and empowering.

7.2 Decision on Joining CDIO Officially or Unofficially

This study provides the background of CDIO in relation to the context of KoRa. This will aid in the decision of joining CDIO.

CDIO is not prescriptive. However programmes willing to conform to the CDIO standards need to audit their curriculum, teaching, learning, and work spaces. To adopt the CDIO framework, an engineering programme should follow the CDIO guidelines, which are defined within twelve CDIO standards. In doing so, programmes undergoing change can have access to open source resources that share best practices while benefiting from and contributing to the CDIO network's parallel efforts for engineering education reform. Using this networked platform reduces the amount resources, time, and effort needed reform an engineering education programme. (Crawley, et al., 2007)

Many engineering programmes are developing independently with a direction that is aligned with the CDIO standards. Also, many movements have the same take on engineering education and the need for development. In my opinion the main benefit of CDIO is the **access to a network of collaborators** who are dealing with the common challenge of engineering education reform. Becoming a part of CDIO will:

a) Enforce strategic objectives of Aalto in terms of
   - Increased international collaboration
   - Increased faculty mobility
   - Improved learner-centred culture

b) Increase international recognition of the programmes involved (marketing)

On the downside, I have understood that there are individuals within the CDIO community, who advocate the standards religiously. It is embedded in university culture, that standards are followed to the point. If people fail to understand that CDIO should be flexible and not prescriptive, the result may be strict and rigid implementation of CDIO standards, which may be detrimental to courses and content that are already well-rounded, functional, and supportive of intended learning outcomes. Not joining CDIO officially will exempt the threat of prescriptive abidance to the CDIO standards. Joining CDIO officially may open up a network for international collaboration.

7.3 Proposals for Future Research

This study will close with three proposals for future research:

1. Implement the suggested tools, document the progress, and develop new tools continuously.
2. Rethink the content of the degree programmes to cater to the demands of the unknown future.
3. Reassess the procedure, schedules, and formats for Thesis works. The world is developing at a fast pace and information is becoming concise, should it be possible to bundle a Thesis out of a series of articles?

Further suggestions for future research on a small scale can be derived from the workshop feedback. The following topics should be addressed in workshops or implemented in short and quick development projects:

- Workshop topics:
    - How to select and initiate appropriate student projects for different stages of studies
    - Learner-centred curriculum planning (a black box workshop)
    - Ethics, responsibility, and leadership as a part of engineering education
- Short and quick development projects:
    - Renovation of teaching and learning spaces with small budgets
    - Integration of international operation into a course
    - Integration of research into education (e.g. ICE BRCR prototype)
    - Implementing CDIO in selected courses/programmes
    - Implementing blended learning in selected courses

My hope is that the suggested tools help to meet the desired CDIO standards, fix issues that were pointed out during the TEE, and play a part in producing graduates that are capable of contributing to the accomplishment of the Grand Challenges. Nevertheless, KoRa should continue implementing studies like this to develop the engineering programmes. Even if one study addresses today's challenges, the educational environment may sway into any direction and require reassessment. Future engineers and engineering educators will be in need of an entirely new set of design and engineering tools in order to contribute to the solving of the future challenges.

"The best way to predict the future is to invent it"

- *Alan Kay*

Technology is evolving and mechanical engineering with it. It has been strongly established that bio-, nanotechnologies, and information technologies are the technological frontiers on this century. Therefore, studying the fundamentals of biomechanics, nanomechanics, and information systems should be considered strongly in the mechanical engineering degree programmes of Aalto.

"...technology is human activity in society for society..."

-Panu Nykänen (Helsinki University of Technology - TKK, 2008)

The organisation of KoRa will need to develop to enforce this truth. In a presentation, Kristina Edström, an educational developer and CDIO expert from KTH[29], stated her law of organisational gravity: *"There is a force acting on education programs to reflect the inherent characteristics of the organization providing it."* In other words the faculty are truly role models for their students. In the case of Aalto, if the university organisation reflects on the students, the university is a poor role model for interdisciplinary collaboration since department faculty are generally stuck within the silos of their own discipline, university bureaucracy is very strict and limiting, and the organisation is built for science within discipline. The point is that the faculty of KoRa should be multidisciplinary. KoRa could develop significantly by hiring game developers, designers, journalists and writers, programmers, and business analysts – not mainly mechanical engineers (who will be needed in other parts of Aalto's faculty). The KoRa faculty has been getting more and more interdisciplinary during my time at Otaniemi. I hope we continue to evolve.

[29] The Royal Institute of Technology in Stockholm

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Appendix

A. Workshop Material

Workshop Diary - CDIO In Aalto University's Department of Engineering Design and Production 14.06.2011 @ Aalto Design Factory - Studio

1 Part 1: Past, Present & Future

1.1 Past: Lessons from the past

1.1.1 What have we been doing well? What should be continued?

1.1.2 What advantages does our history bring?

1.2 Present: Lessons from TEE and ongoing educational development initiatives:

1.2.1 What is the current state of teaching in our department?

1.2.2 How well do our educational programs provide students with skills the present requirements for graduating engineers (e.g. skills mentioned in a job advertisement)?

1.3 Future: Strategic objectives of the future:

1.3.1 What will be the requirements for engineering graduates in 2020?

1.3.2 How will students be taught then? What methods and tools will be used in teaching?

2 Part 2: Integrating CDIO

2.1 Existing Exercise of Interpersonal Skills: What interpersonal skills **ARE ALREADY** integrated into engineering courses?

2.2 Integrating Interpersonal Skills: What interpersonal skills **CAN BE** integrated into engineering courses?

2.3 A Redesign of the Program Structure: Instead of changing the existing courses to incorporate more interpersonal skill development, can it be done by having the students continuously involved in multidisciplinary projects?

3 Part 3: Putting the plans to Practice

3.1 Bachelor's Degree Programs

3.1.1 How can it be developed?

3.1.2 What are your goals for it by 2020? Map out the structures for the programs at a modular level.

3.1.3 What kind of role would you like to have in the development of the master's program?

3.2 Marter's Degree Programs

3.2.1 How can it be developed?

3.2.2 What are your goals for it by 2020? Map out the structures for the programs at a modular level.

3.2.3 What kind of role would you like to have in the development of the master's program?

4 Feedback for Workshop Arrangements and Future Workshops

4.1 Was the workshop useful? Yes No

4.2 Grade for the workshop. 0… 5 ____

4.3 The workshop is designed to be iterative

4.3.1 How frequently should it be held Never Annually Monthly

4.3.2 Based on this workshop, what three themes should be covered in KoRa's next CDIO workshop?

Part 1:______________________________

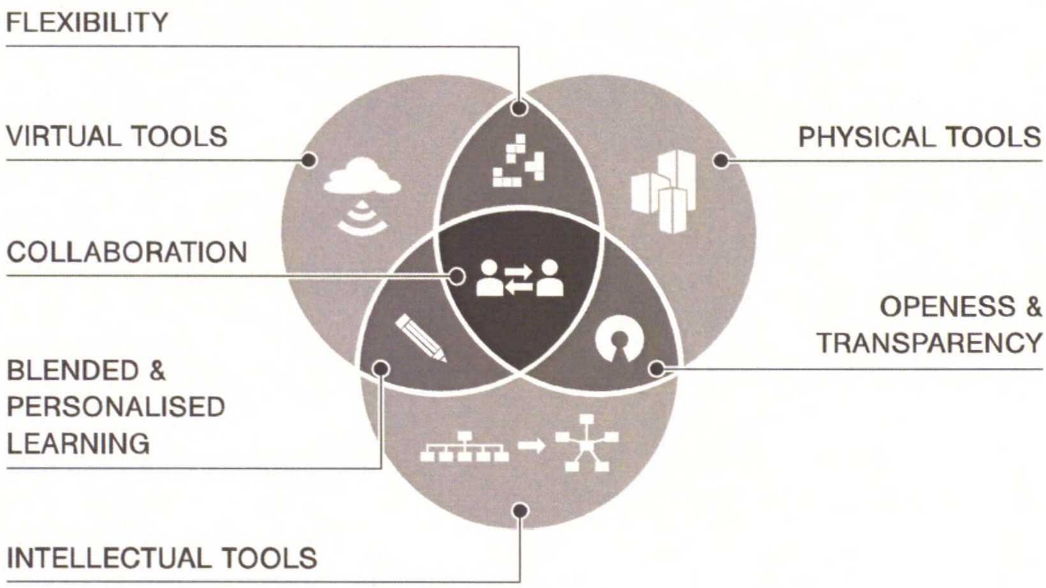
Part 2:______________________________

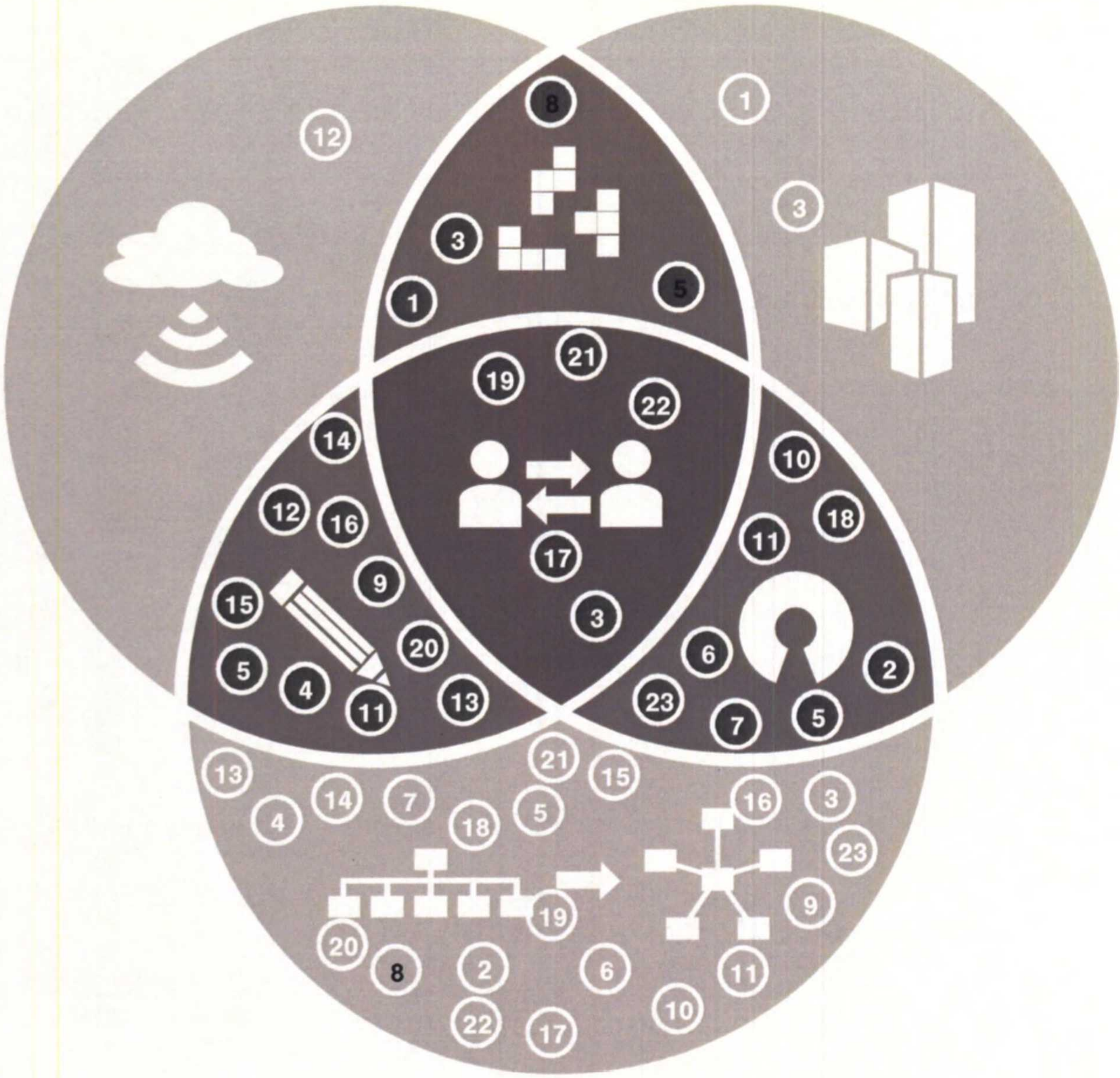
Part 3:______________________________

4.3.3 Could it work for themes other than CDIO in KoRa? Yes No

4.3.4 Free words about the workshop:

B. Best Practice Cards



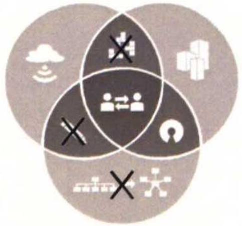


1 Excellent Facilities
2 Guidance of Students
3 Interdisciplinary Teaching
4 Personalised Learning
5 Access to Teachers
6 Scheduling Studies
7 Positive Atmosphere
8 Flexible Programme
9 Integrated Learning
10 Research in Teaching
11 Effective Use of Feedback
12 Use of Virtual Tools
13 Variety in Teaching
14 Pedagogical Awareness
15 Personal Assessment
16 Professional Development
17 Internationalisation
18 Clear Objectives
19 Stakeholder Involvement
20 PBL
21 Collaborating Faculty
22 Open to Collaborate
23 Programme Evaluation and Development

The numbers that appear in black in the figure above do not meet the set criteria for desired overlaps. However, the relative placement of tools and attitudes is the most favourable in the displayed arrangement. The following pages are the evaluations of the best practices.

1. Access to Teachers

Reduced Group Sizes, Increased Number of Teachers



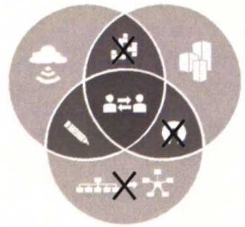
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence, 11 Learning Assessment

Discovered in: School of Chemical Technology, Chemical Technology

Implementing teaching: Also, group sizes were decreased and the number of teachers was increased.

2. Access to Teachers

Teachers are Accessible



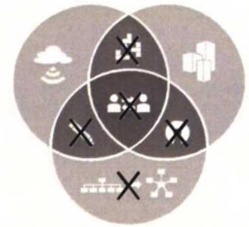
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: The School of Engineering, Mechanical Engineering

Evaluation and Development: Teachers are stated by students to be easily accessible.

3. Access to Teachers

Professors and Instructors are Very Involved in Students' Personal Development



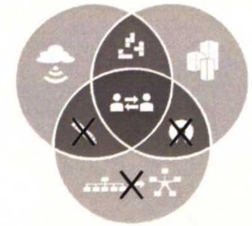
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Film and Television BA+MA

Implementing teaching: The professors and instructors are very much involved in the personal development of their students and do make every effort to make their transition into the industry as smooth as possible.

4. Access to Teachers

Formalised Guidance of Students' Written Assignments*



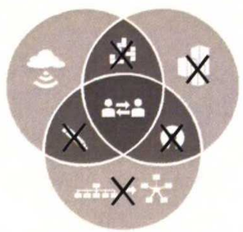
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Fine Arts

Evaluation and Development: The teaching staff will need to organize more formalized guidance for the students' written assignments in the future.

5. Access to Teachers

Informal Meetings, Like Soup Lunches for Teachers and Students, Create Dialog



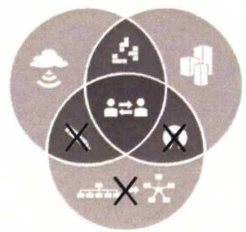
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Evaluation and Development: Informal meetings (like the soup lunches in Production Design for Film and Television) are valuable – and efficient – opportunities for teachers and students to discuss things.

6. Access to Teachers

All Teachers Teach in the Introductory Course to Introduce Themselves



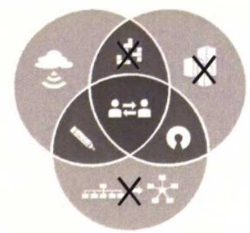
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Art & Design, Creative Business Management and Visual Culture MA

Evaluation and Development: The introductory course introduces all the teachers and the areas of their interests. Everyone teaches for a day and this gives an idea of teachers' individual approaches to teaching.

7. Access to Teachers

A student Club that has appreciated communication with staff



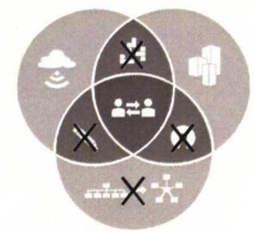
Related CDIO Standard(s): 9 Enhancement of Faculty Competence, 12 Programme Evaluation

Discovered in: School of Economics, Communication in Business and Economy, MSc and International Business Communication, MSc

Implementing teaching: The 'Communication Student Club' is appreciated by students as a way of engaging with other students and staff.

8. Clear Objectives

Content Renewal is Common, but Consistency remains



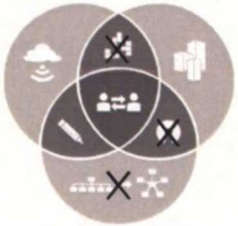
Related CDIO Standard(s): 12 Programme Evaluation, 2 Learning Outcomes

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Implementing teaching: The content of studies should not change too often so that it remains consistent.

9. Clear Objectives

Successful trimming and pruning of the course portfolio to the bare essentials



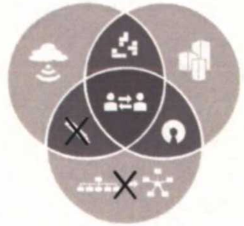
Related CDIO Standard(s): 12 Programme Evaluation, 2 Learning Outcomes

Discovered in: School of Economics, Marketing, MSc

Planning and Management: Successful trimming and pruning of the course portfolio to the bare essentials. The MSc in Marketing, has been successful in clustering courses around core marketing competencies.

10. Clear Objectives

Top-down programme planning has led to well-related Master's level courses



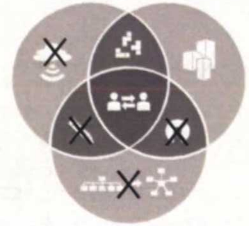
Related CDIO Standard(s): 12 Programme Evaluation, 3 Integrated Curriculum

Discovered in: School of Electrical Engineering, Communications Engineering and Master's Programme in Communications Engineering

Planning and Management: The top-down programme planning has led to well-related Master's level courses

11. Clear Objectives

Mapping of Core Competences



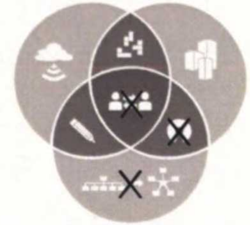
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Energy and HVAC-Technology

Planning and Management: The ambitious mapping of core competences on courses identifies and gives a clear description of how programme objectives, both subject-connected and more general, can be reached.

12. Clear Objectives

Structured Approach that fulfils Stakeholder Needs



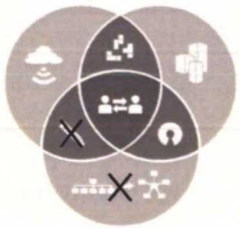
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Master's programme in Real Estate Investment and Finance

Planning and Management: A structured approach is used to fulfil the needs of stakeholders in the international market.

13. Clear Objectives

Working on More Focus for courses



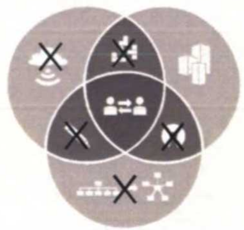
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: working on more focus for the course

14. Clear Objectives

Clear Competence Areas Directs First Year Teaching



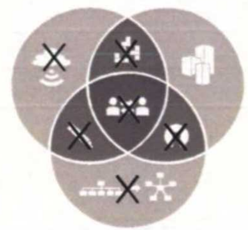
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: There are 8 clear competence areas that give a strong direction for teaching in the first year; students are engaged in all the relevant topics

15. Clear Objectives

Collaborative Learning Objectives and Knowledge Building with a Wiki



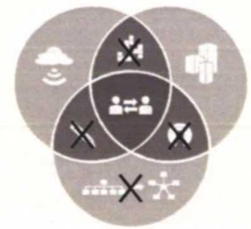
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Art Education and ePedagogy

Implementing teaching: A collaborative learning objective is the result of a collaborative knowledge building process in a wiki that includes key information written by the discussion attendees.

16. Clear Objectives

Optional Studies Have Clearly Defined Objectives



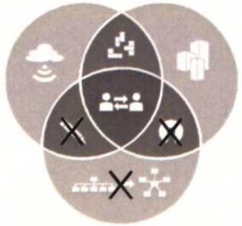
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Implementing teaching: Optional studies are clearly described with their objectives and contents outlined (especially in the MA studies).

17. Clear Objectives

Explicit Goals of Basic Studies Help the Learning Process



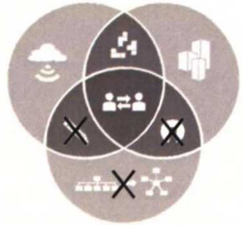
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Environmental Art

Implementing teaching: The goals of the basic studies must be more explicit to help the learning process.

18. Clear Objectives

Clear Assessment Criteria



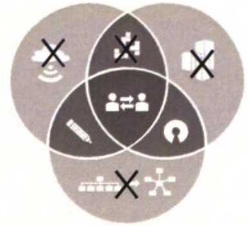
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Planning and Management: There are clear assessment criteria.

19. Clear Objectives

Comprehensive Combination of Courses



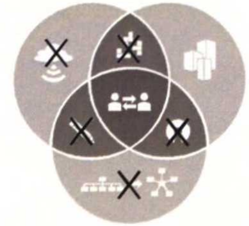
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: The School of Engineering, Real Estate Economics

Planning and Management: Ability to combine the courses into a comprehensive entirety of a programme offering added value.

20. Clear Objectives

Basic Studies Have a Close Connection to Other Studies



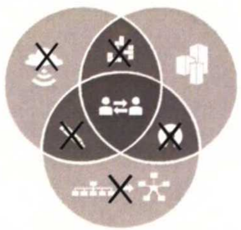
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Art & Design, Art Education and ePedagogy

Implementing teaching: The purpose is that basic study courses will then have a close connection with other studies.

21. Clear Objectives

The Process of HOPS Creation is Highly Beneficial to Students



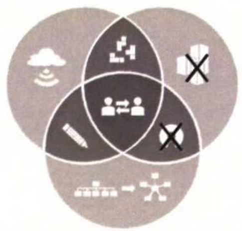
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Chemical Technology, Chemical Technology

Planning and Management: The counselling process is highly beneficial from the student's perspective. The personal study plan (HOPS) is an effective tool for planning the studies. The process in which making the HOPS is first guided by the student advisor and finally approved bythe study co-ordinator insures that both the student's individual interests and the career relevance of the curriculum are taken into account.

22. Clear Objectives

Information event for freshmen



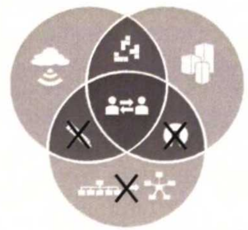
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Chemical Technology, Material Science and Engineering

Implementing teaching: The information event for freshmen a few weeks after they have begun their studies clarifies the most important study issues

23. Clear Objectives

introductory courses for first-year students



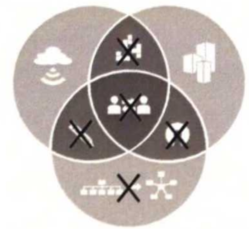
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Electrical Engineering, Automation and Systems Technology

Planning and Management: The planned introductory courses for first-year students in Automation and Robotics

24. Collaborating Faculty

Team Teaching/ Co-Teaching



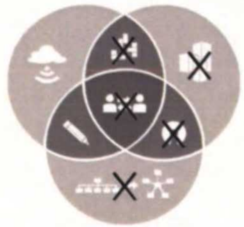
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Implementing teaching: In Photography and Graphic Design there is a common practice of Team teaching and/or co-teaching, although the staff feels a need for more resources to expand this practice.

25. Collaborating Faculty

Teachers Meeting on the Last Friday of every Month



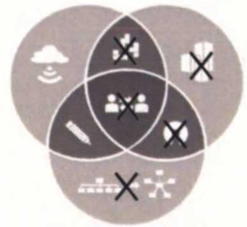
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Chemical Technology, Chemical Technology

Evaluation and Development: The Degree Programme Committee decided to organise a Teachers' Day in August 2010 for teachers of the School of Chemical Technology. A need for continuous discussions between teachers was obvious and a teachers' meeting on the last Friday morning of everymonth was initiated.

26. Collaborating Faculty

co-teaching ,enabled good practice to spread, allowed paired staff to discuss teaching and assessment practice, and facilitated orientation of new staff



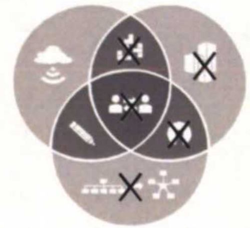
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Economics, Management

Implementing teaching: The practice of co-teaching has enabled good pedagogic practice to spread through the teaching team, allowing paired staff to discuss their teaching and assessment practice in depth and facilitated the induction and orientation of new staff

27. Collaborating Faculty

co-teaching as a core value, even if there are no budgetary incentives



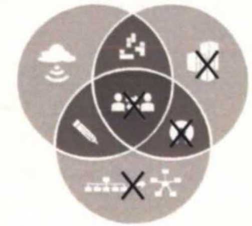
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Economics, Marketing, BSc

Planning and Management: Institute co-teaching as a core value, even if there are no budgetary incentives within ASE or AU for co-teaching. Moreover, they willingly engage with each other as coachers and co-learning partners of their students.

28. Collaborating Faculty

Biannual teaching development days to disseminate information and coordinate curriculum development



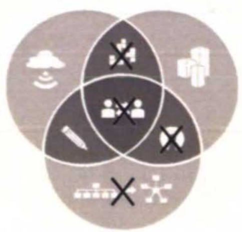
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Electrical Engineering, Communications Engineering and Master's Programme in Communications Engineering

Implementing teaching: Biannual teaching development days are arranged to disseminate information among the teachers and to coordinate the curriculum development work

29. Collaborating Faculty

Entrance Assessment by Other Programmes' Staff



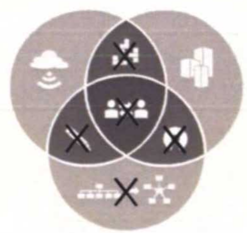
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: Participation by teaching staff in the entrance assessments of other programmes

30. Collaborating Faculty

Programmes Taking Joint Responsibility to Develop



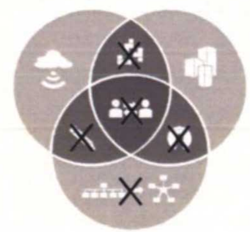
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: The fact that the programmes are taking joint responsibility to redress the balance between core subject/studies and electives in response to the previous process of defragmentation

31. Collaborating Faculty

Synergy Found with Shared Programmes



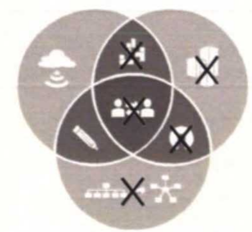
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Planning and Management: A firm decision to put a new Media Lab, and a graphic design and photography unit, in the same Department: a common synergy was found with shared areas of interest

32. Collaborating Faculty

Cooperative work, new ways of collecting feedback, and feedback evaluation are used to create a joint course



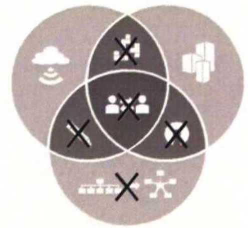
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Chemical Technology, Material Science and Engineering

Evaluation and Development: One example of joint course co-operation might be given by the course MT- 0.2201 "Basics of Materials Chemistry" by two teachers. This course was developed jointly and started in 2006. As a result of co-operative work, a new method of collecting students'feedback and their evaluation in the form of lecture diaries was implemented. Every student writes a one-to-two page summary of the lecture topics and submits it electronically to the respective teacher within two weeks after the lecture. Copying text/slides or inclusion of other text is not accepted. Instead, there is a requirement that the student will assess the subject critically, comment upon it and also give feedback to the teacher at the end, explaining, for example, how difficult this particulartopic was to understand, how clearly the presentation materials were given, etc. The teacher assesses the diary, and the mark is given during the next week. Close co-operation between these teachers was required to correlate lecture materials, to developjoint and consistent evaluation principles (every period evaluated separately) as well as to integrate the total marks for students' knowledge assessment for the whole course.

33. Collaborating Faculty

Cross-disciplinarily by Sharing Teachers



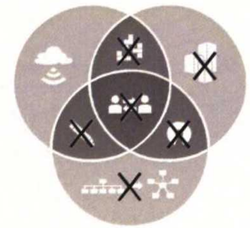
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Implementing teaching: There is a positive tendency towards cross-disciplinarily by the sharing of teachers in various courses and individual projects.

34. Collaborating Faculty

Small Groups, Cooperation within Programme and Between Departments



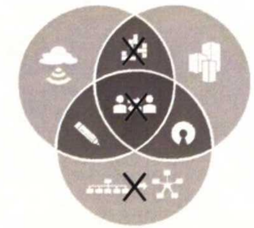
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Implementing teaching: The degree programmes are usually small peer groups and allow close contact; Cooperation is encouraged within the programmes, and this co-operation is emerging between programmes within the Department of Media.

35. Collaborating Faculty

Seeking opportunities for multi-disciplinary engagement with other Departments or Schools



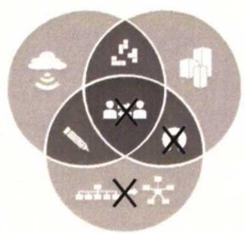
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, Business Law, MSc

Planning and Management: The faculty and staff of Business Law appear to be actively seeking to complement their expertise with respect to teaching, curriculum development, and research by finding opportunities for cross-fertilization or multi-disciplinary engagement with other Departments or Schools, both at the ASE level and at the AU level and at other universities in Helsinki and Finland.

36. Collaborating Faculty

Good Cooperation Amongst Staff



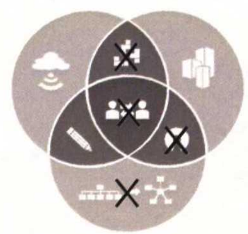
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: The School of Engineering, Landscape Architecture

Evaluation and Development: There is clearly very good cooperation amongst staff, although clearer definition of roles is required.

37. Collaborating Faculty

Shared Informative Manifesto of Strategy



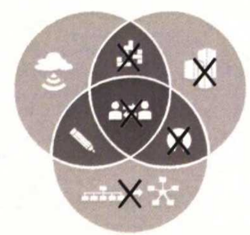
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: A shared manifesto which informs the vision the values and the strategic planning of the constituent programmes

38. Collaborating Faculty

Willingness and Openness to Co-operate and Share among faculty



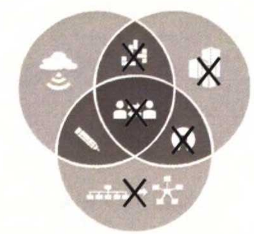
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: A willingness and openness to co-operate, evidenced by joint project-working, courses, entry examination assessments and sharing of teaching methods

39. Collaborating Faculty

Day Retreats for Teachers Where Strategy is Discussed



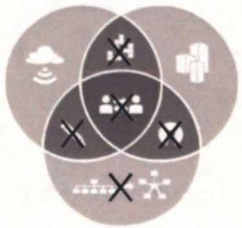
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Art & Design, Creative Business Management and Visual Culture MA

Planning and Management: The programme has day retreats for teachers where all important strategic questions are discussed.

40. Collaborating Faculty

Dedicated Teachers Invited According to Project Themes



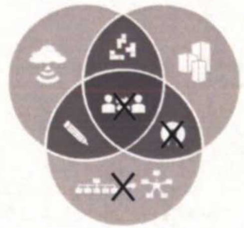
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Art & Design, Environmental Art

Planning and Management: The staff can invite different kinds of dedicated teachers according to the theme of the project.

41. Collaborating Faculty

Sharing of Courses and Research Methods



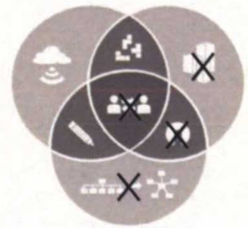
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Evaluation and Development: Common courses and research methods are shared.

42. Collaborating Faculty

Teacher's Café.



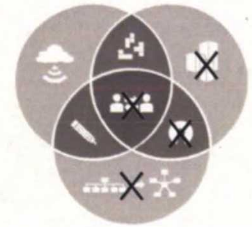
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Electrical Engineering, Bioinformation Technology

Planning and Management: BECS Teacher's Café.*

43. Collaborating Faculty

Team work among the staff



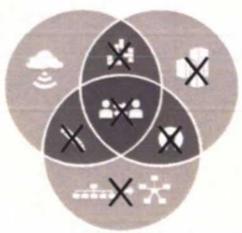
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: The School of Science, Computer Science and Engineering and Master's Programmes in Mobile Computing – Services and Security, Foundations of Advanced Computing, Machine Learning and Data Mining, Service Design and Engineering and Bioinformatics

Planning and Management: The team work among the staff is also a crucial resource to nourish for the future.

44. Collaborating Faculty

Strong teacher co-operation in making the programme work effectively



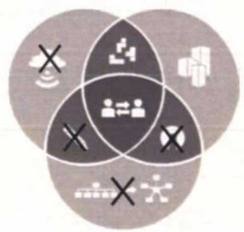
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: The School of Science, Information Networks

Evaluation and Development: Strong teacher co-operation in making the programme work effectively

45. Effective Use of Feedback

Feedback Supports Individual Learning



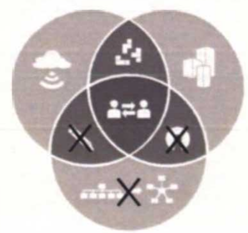
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: The School of Engineering, Transportation and Environmental Engineering

Implementing teaching: The same applies to examination philosophy as stated. The system of giving feedback on assignments strongly supports the individual learning process. For the development of new education formats an elaboration of this feedback system might be very helpful.

46. Effective Use of Feedback

A lot of Feedback for Personal Development



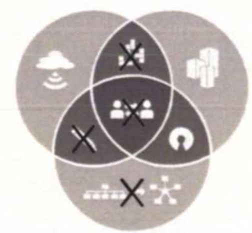
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Film and Television BA+MA

Evaluation and Development: Receiving a great deal of feedback increases the student's understanding of his/her abilities and their knowledge of the process.

47. Effective Use of Feedback

Oral Evaluation is Common and Highly Appreciated



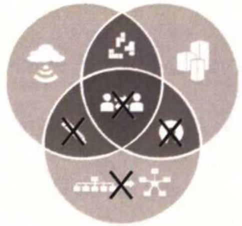
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Evaluation and Development: Oral evaluation is the most common method of evaluation and is highly appreciated by students and staff. The panel would like to stress that this method lacks transferability and transparency of information to monitor the overall student learning process.

48. Effective Use of Feedback

Active Feedback Between Faculty and Students



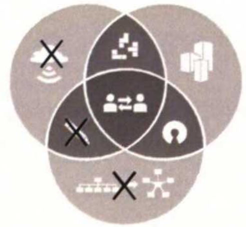
Related CDIO Standard(s): 11 Learning Assessment, 12 Programme Evaluation

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Planning and Management: There is active feedback between faculties and students.

49. Effective Use of Feedback

Collecting feedback in connection with assignments as an alternative to Oodi



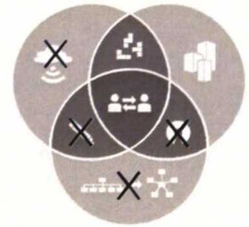
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Chemical Technology, Material Science and Engineering

Evaluation and Development: A good example of a successful (non PalauteOodi) method for collecting and utilising feedback is the course MT-0.2216 Unit processes and mechanisms. Student feedback is collected during the course in connection with lecture assignments. This has been seento be an effective way to develop the course while it is still running. Students are motivated to answer, as they feel that they can influence the course. It helps the teacher to see whether the learning objectives have been reached as planned and to clarify things that have been unclear for the students.

50. Effective Use of Feedback

Feedback is Well Collected, Monitored and Acted On



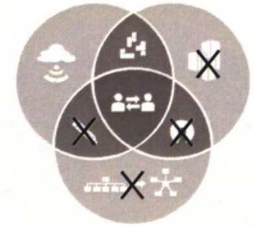
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Engineering, Landscape Architecture

Evaluation and Development: The way in which student feedback is collected, monitored and acted on is an excellent precedent

51. Effective Use of Feedback

Effective Methods for Collecting Feedback



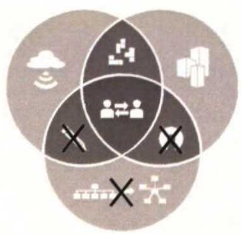
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Engineering, Transportation and Environmental Engineering

Evaluation and Development: Before the new feedback system was implemented, very efficient methods for collecting feedback and discussing the results with students existed, at least in some courses. In some cases this led to an immediate improvement, especially during the introductory phase of new educational formats. (q17). It seems that the new feedback system is not properly functioning for this purpose, which leads to frustration from the students and teachers.

52. Effective Use of Feedback

Effective student feedback



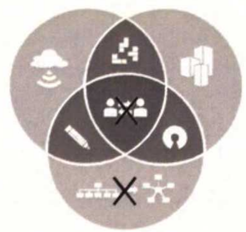
Related CDIO Standard(s): 12 Programme Evaluation, 12 Programme Evaluation

Discovered in: School of Economics, Business Technology, BSc and Information and Service Management, MSc

Evaluation and Development: Effective student feedback

53. Effective Use of Feedback

Blind marking coursework with new teachers to give an understanding of the academic standard



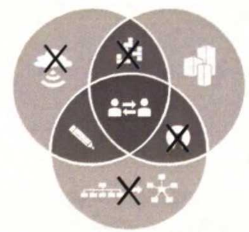
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Communication in Business and Economy, MSc and International Business Communication, MSc

Implementing teaching: The Programme Director of the Communication Business and Economy programme supports new teachers in gaining understanding of academic standards through blind marking of coursework (new teacher and Programme Director separately) with subsequent discussion.

54. Effective Use of Feedback

Good feedback response rates with feedback used to determine future delivery



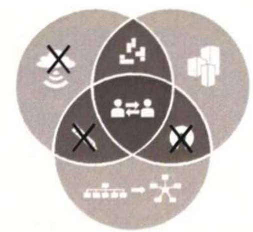
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Evaluation and Development: Good feedback response rates with feedback used to determine future delivery

55. Effective Use of Feedback

Use of a student "well being" survey.



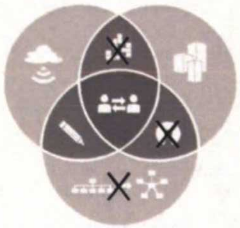
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Science, Engineering Physics and Mathematics

Evaluation and Development: Use of a student "well being" survey.

56. Effective Use of Feedback

A proactive programme committee that embraces course feedback



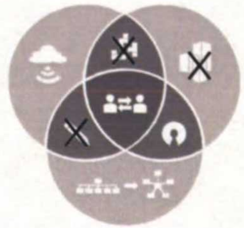
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Science, Information Networks

Evaluation and Development: A proactive programme committee that embraces course feedback

57. Excellent Facilities

Excellent Workshops



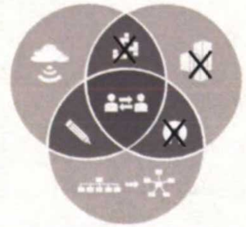
Related CDIO Standard(s): 6 Engineering Workspaces,

Discovered in: The School of Engineering, Architecture

Implementing teaching: excellent workshops

58. Excellent Facilities

Excellent facilities



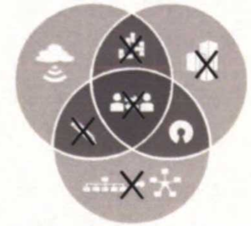
Related CDIO Standard(s): 6 Engineering Workspaces,

Discovered in: School of Electrical Engineering, Automation and Systems Technology

Implementing teaching: Excellent facilities

59. Excellent Facilities

Facilities from web-based learning environments to the mass lecture environment



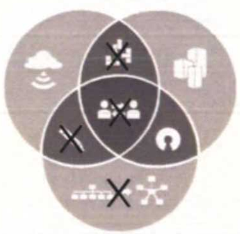
Related CDIO Standard(s): 6 Engineering Workspaces,

Discovered in: The School of Science, Industrial Engineering and Management and Master's Programmes in Service Management and Engineering and Strategy

Implementing teaching: Overall organization and implementation of web-based learning environments to the mass lecture environment enabling more emphasis on assignment-based evaluation.

60. Flexible Programme

Disciplinary Variety Prepares Continuing BA Students



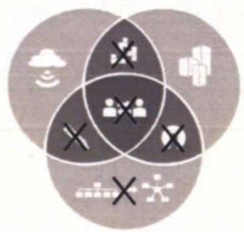
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: focus very much on a variety of disciplines and backgrounds to supplement the continuing TAIK BA students

61. Flexible Programme

Programme Suitable for Linking to Other Studies



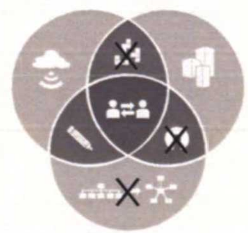
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: The School of Engineering, Landscape Architecture

Planning and Management: Landscape Architecture is an ideal programme at both BA and MA levels for linking the learning outcomes of courses and modules (for a, b, c), both between the Aalto Schools and programmes, and other Finnish and regional centres and international programmes.

62. Flexible Programme

Flexible Programme



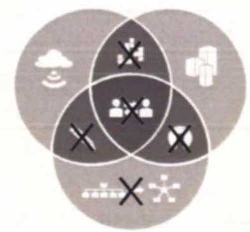
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: The School of Engineering, Real Estate Economics

Planning and Management: Flexibility of programme.

63. Flexible Programme

Degree Includes Optional or International Studies



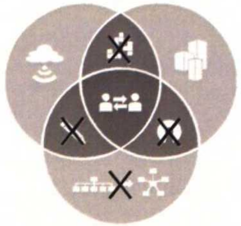
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Implementing teaching: The degree includes at least 20 credits for optional or international studies; credits received elsewhere are accepted.

64. Flexible Programme

Possibility for Customised Options and Minor



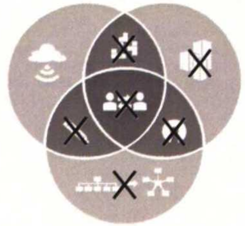
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Implementing teaching: There is a logical and structural opportunity to create one's own "path" with optional and minor studies.

65. Flexible Programme

The programme is open to change based on the development of the subject area, the teachers' experience and the students' evaluations.



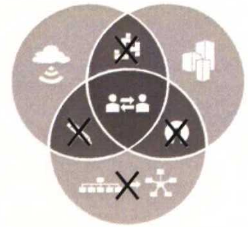
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: The School of Science, Computer Science and Engineering and Master's Programmes in Mobile Computing – Services and Security, Foundations of Advanced Computing, Machine Learning and Data Mining, Service Design and Engineering and Bioinformatics

Evaluation and Development: The programme is open to change based on the development of the subject area, the teachers' experience and the students' evaluations.

66. Flexible Programme

Flexibility of study choices for students



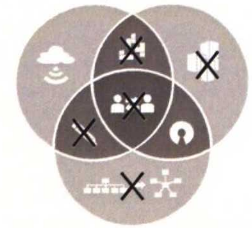
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: The School of Science, Information Networks

Planning and Management: Flexibility of study choices for students

67. Flexible Programme

Support of Mobility



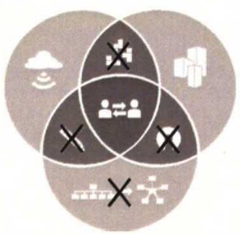
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: The School of Engineering, Architecture

Planning and Management: support of mobility

68. Flexible Programme

Service Teaching: two option models for different purposes (programme students and students from other programmes)



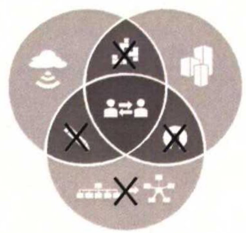
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: The School of Science, Industrial Engineering and Management and Master's Programmes in Service Management and Engineering and Strategy

Implementing teaching: Service teaching: two option models for different purposes (programme students and students from other programmes).

69. Flexible Programme

Small and Flexible Program



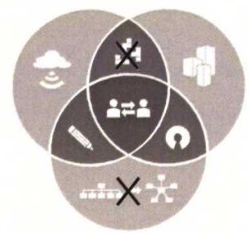
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: The furniture design programme is small and flexible

70. Flexible Programme

Summer programme



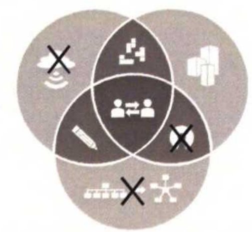
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Economics, Business Technology, BSc and Information and Service Management, MSc

Planning and Management: Summer programme

71. Guidance of Students

Reception of Students



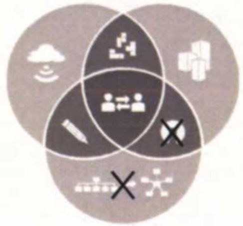
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: The School of Engineering, Mechanical Engineering

Implementing teaching: Reception of the students at the beginning, where students are allocated a "student mentor".

72. Guidance of Students

Students Integrated into Everyday Practice



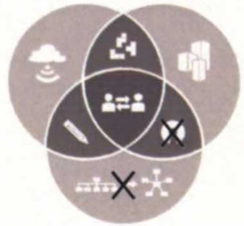
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: The School of Engineering, Master's Programme in Environmental Technology (Lahti)

Implementing teaching: Students have been successfully integrated into the everyday practice of education, tutoring and guidance within the programme (although until now there has been no systematic approach).

73. Guidance of Students

Students Integrated into Everyday Practice



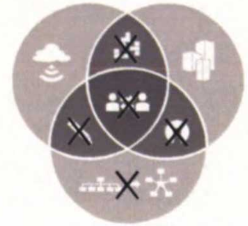
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: The School of Engineering, Real Estate Economics

Implementing teaching: Integrating students successfully into everyday practice of education, tutoring and guidance within the programme.

74. Integrated Learning

Dialogue with Peers, Teachers, Collaborators, and Public Ensures Relevance



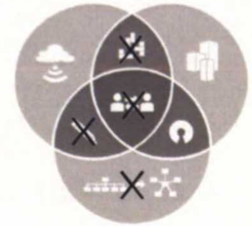
Related CDIO Standard(s): 1 The Context, 12 Programme Evaluation

Discovered in: School of Art & Design, Environmental Art

Implementing teaching: There are discussions among peers to ensure the relevance of the topics and there is also guidance from the external teachers/collaborators involved as well as feedback from the public that might share the experience of the projects, but there are no formal feedback procedures in place.

75. Integrated Learning

collegiality between the programme and the Language and Communication Department



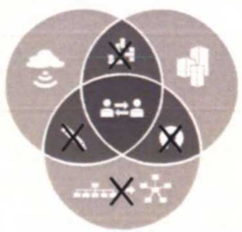
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Economics, Management

Planning and Management: The high level of collegiality between the programme and the Language and Communication Department brings a more coherent provision

76. Integrated Learning

BA Thesis with Research Methodology, Language and Information skills



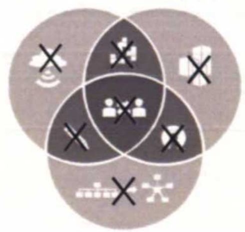
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Art Education and ePedagogy

Implementing teaching: In the Art Education BA thesis, seminars are integrated with a research methodology course and two courses of basic studies: mother tongue studies and information skills.

77. Integrated Learning

Integrated Learning Environment in a PBL Setting



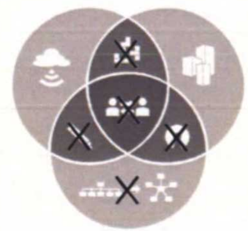
Related CDIO Standard(s): 7 Integrated Learning Experiences, 8 Active Learning

Discovered in: School of Art & Design, Art Education and ePedagogy

Implementing teaching: In ePedagogy the didactical design contains cross-references to a problem-based learning setting with themed discussion boards, online resources, tele-lectures, as well as synchronous and asynchronous communication.

78. Integrated Learning

Encouraging Sharing Project and Discussing within Communities



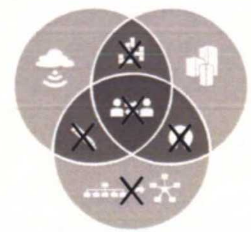
Related CDIO Standard(s): 7 Integrated Learning Experiences, 8 Active Learning

Discovered in: School of Art & Design, Creative Business Management and Visual Culture MA

Planning and Management: Students are encouraged to share their own projects and learn to discuss and reflect work in a community.

79. Integrated Learning

Students Contribute to Group discussions and Reflect on Projects to Obtain Feedback



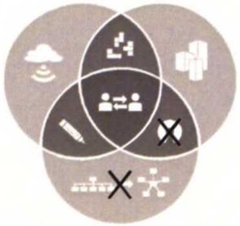
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Environmental Art

Evaluation and Development: It must be a formalised part of the study for students to contribute to discussions in the group and to be able to reflect on the projects both verbally and in writing to obtain realistic feedback.

80. Integrated Learning

Useful Studies From other Disciplines are Obligatory



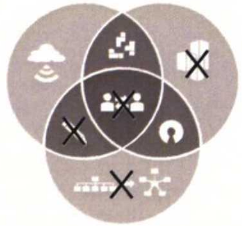
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Fine Arts

Implementing teaching: Non-art studies, such as philosophy, politics and social sciences, are obligatory and they offer an exciting menu for the emergent artists.

81. Integrated Learning

focus on student co-operative learning



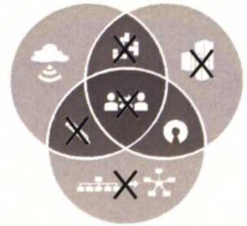
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, Management

Implementing teaching: focus on student co-operative learning particularly in the Master's course and years 2 and 3 of the Bachelor's programme

82. Integrated Learning

large lecture-style classrooms, supplemented with smaller interactive workshops designed to deepen learning and build skills



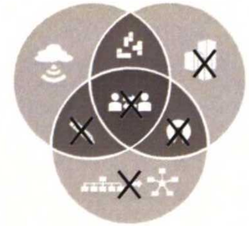
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, Marketing, MSc

Implementing teaching: The Introduction to Marketing course could be a role model for other introductory courses on how to engage students in large lecture-style classrooms, supplemented with smaller interactive workshops designed to deepen learning and build skills.

83. Integrated Learning

The Bachelor's thesis scientific conference



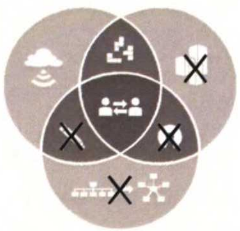
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Electrical Engineering, Bioinformation Technology

Implementing teaching: The Bachelor's thesis scientific conference

84. Integrated Learning

Excursions, Industry Lectures, and Laboratory Examples Show the Context



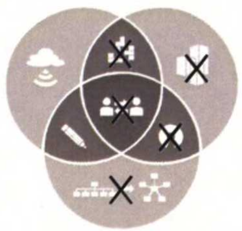
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Chemical Technology, Chemical Technology

Implementing teaching: In general, motivating students by showing them the relevance of the subject to be learnt (excursions, examples from industry in lectures, everyday samples and processes in laboratory work) has proven important.

85. Interdisciplinary Teaching

Integration of Disciplines. School level Quality of Education Committee



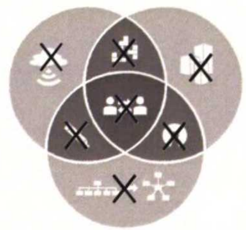
Related CDIO Standard(s): 1 The Context,

Discovered in: School of Electrical Engineering, Automation and Systems Technology

Evaluation and Development: Integration of disciplines: The planned course on Electronics and analogy control. School level: OpLaa.

86. Interdisciplinary Teaching

The multi-disciplinary nature of the programme structure



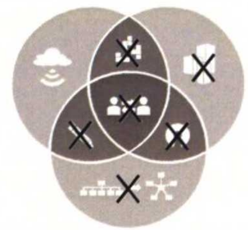
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: The School of Science, Information Networks

Planning and Management: The multi-disciplinary nature of the programme structure

87. Interdisciplinary Teaching

Interdisciplinary Project Experiences



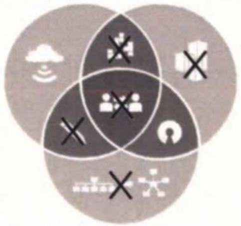
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: The School of Engineering, Master's programme in Real Estate Investment and Finance

Planning and Management: Cross-disciplinary and multidisciplinary research project experiences are included in the programme planning.

88. Interdisciplinary Teaching

Combination of Lectures and Laboratory Classes



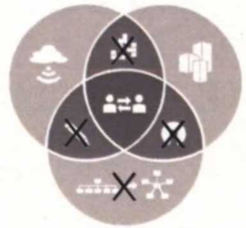
Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Engineering, Structural Engineering and Building Technology

Implementing teaching: The combination of lectures and laboratory classes, where all students are kept interested and busy with collecting information, is a very good practice. The involvement of students from Architecture in these laboratory sessions is also very beneficial, and this should be expanded.

89. Internationalisation

Relatively High Numbers of International Applicants



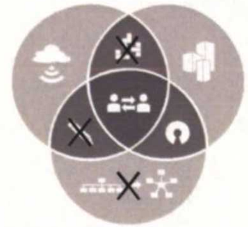
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Planning and Management: There are relatively high numbers of applicants from outside the country.

90. Internationalisation

Exchange Credits are Accepted; Studies are Not Extended



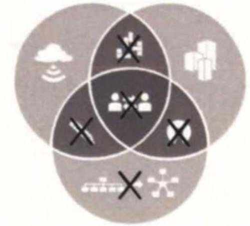
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Planning and Management: Learning agreements work for students who go abroad for a semester. Credits are accepted and going abroad does not actually extend the study period.

91. Internationalisation

Seminar for Exchanging Information on International Studies



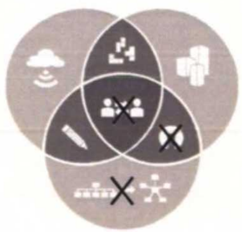
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Art Education and ePedagogy

Planning and Management: The Art Education programme arranges an annual half-day seminar where international exchange students present information about their own institutions and Finnish students share their exchange experiences. This seems to be a successful form for the students to learn about available opportunities of exchange.

92. Internationalisation

International: 60% from Finland 40% from Abroad



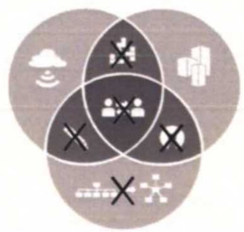
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Fine Arts

Planning and Management: Students come from all over the world (60% from Finland/40% from abroad).

93. Internationalisation

The Programme is Creating a Network of International Experts in the Field



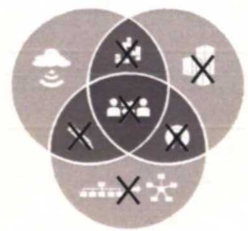
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Evaluation and Development: The programme is creating a network of international experts in the field.

94. Internationalisation

Students Visit Internationally Important Events



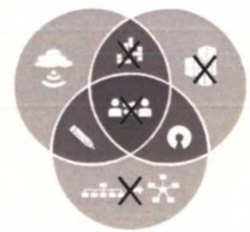
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Evaluation and Development: Students visit internationally important events, e.g. Ars Electronic.

95. Internationalisation

Opportunities to engage in international projects using experiences learnt



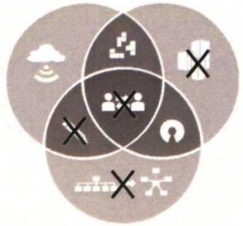
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, Entrepreneurship, MSc

Evaluation and Development: Opportunities to engage in international projects using experiences learnt

96. Internationalisation

Mandatory international exchanges



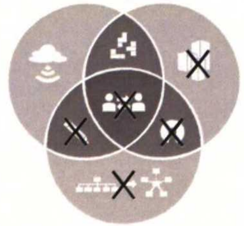
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Implementing teaching: Mandatory international exchanges are a strong part of this programme and are well supported

97. Internationalisation

A strong international community with students coming from many different nationalities



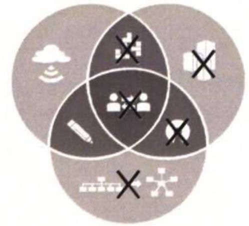
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Implementing teaching: A strong international community with students coming from over forty different nationalities with sixty visiting faculty members from around fifteen countries

98. Internationalisation

Student inclusion on the Advisory Board of global alliance in education



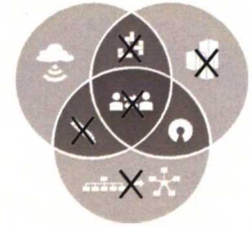
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, International Business, MSc (Helsinki)

Planning and Management: Student inclusion on the Advisory Board of the CEMS is a practice that could be replicated by other programmes

99. Internationalisation

Dual-degree programme agreements with non-Finnish universities



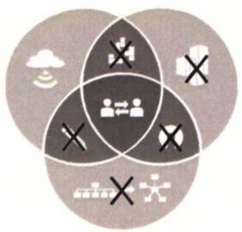
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Electrical Engineering, Communications Engineering and Master's Programme in Communications Engineering

Planning and Management: Dual-degree programme agreements with non-Finnish universities demonstrate international alignment and bench-marking

100. Internationalisation

Clear encouragement of student mobility



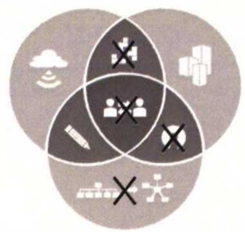
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: The School of Science, Information Networks

Planning and Management: Clear encouragement of student mobility

101. Internationalisation

Initiation of International Experts



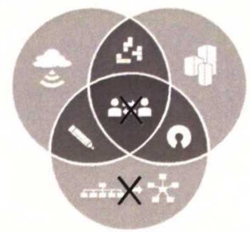
Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Engineering, Master's programme in Real Estate Investment and Finance

Implementing teaching: The programme invited excellent international experts.

102. Internationalisation

Staff Positioned Well in Committees and Associations



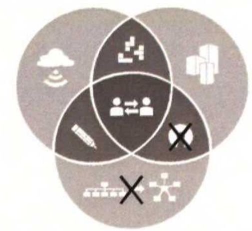
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: The School of Engineering, Geomatics

Evaluation and Development: Members of the staff have leading positions on the educational committees of international associations

103. Internationalisation

Attract and retain faculty who have their doctorates from other universities



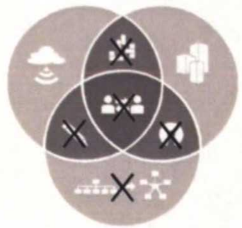
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Marketing, BSc

Planning and Management: Attract and retain faculty who have their doctorates from other (UK) universities

104. Open to Collaborate

Guest Lecturers Keep Give a Contemporary Perspective



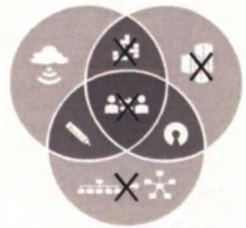
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Implementing teaching: Lecturers from outside the School keep students in a contemporary relationship with the area of their studies.

105. Open to Collaborate

Making use of experienced practitioners for specialized courses



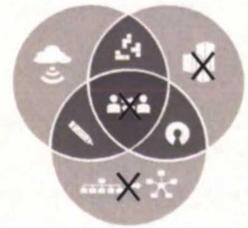
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Economics, Business Law, MSc

Implementing teaching: Given the small scale of the Programme, the faculty must make use of experienced practitioners for specialized courses such as Intellectual Property Rights.

106. Open to Collaborate

Workplace connections



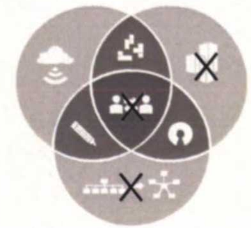
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Economics, Business Technology, BSc and Information and Service Management, MSc

Planning and Management: Workplace connections

107. Open to Collaborate

Workplace connections



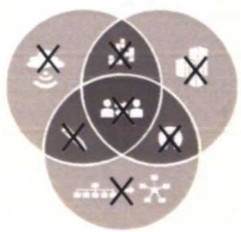
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Economics, Business Technology, BSc and Information and Service Management, MSc

Evaluation and Development: Workplace connections.

108. Open to Collaborate

Building Bridges to Other Departments



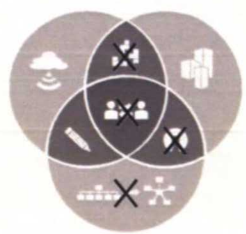
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: The School of Engineering, Geomatics

Planning and Management: GIS is integrating, and building bridges to other Departments and other Schools using spatial information processing

109. Open to Collaborate

Gathering external partners and Supporters



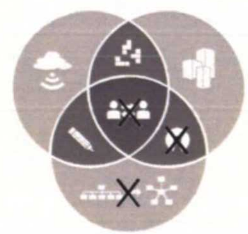
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: The School of Engineering, Master's programme in Real Estate Investment and Finance

Implementing teaching: Broad real-life partnership was built with city and regional councils around Helsinki; the Ministry of the Environment also supported the courses.

110. Open to Collaborate

Common Course as a Part of A Shared Study Programme



Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: There is a common course (30–40 ECTS), as part of the shared study programme

111. Open to Collaborate

Close Co-operation Between Programmes

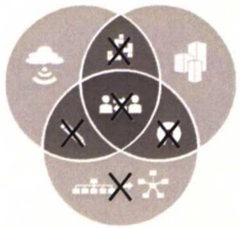
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: close co-operation (between Fashion and Textile) with shared study modules

112. Open to Collaborate

Close Co-operation with Related External Institute



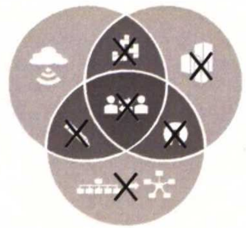
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Planning and Management: Close co-operation between the School of Art and Design and the Theatre Academy is very important.

113. Open to Collaborate

Value-added Collaboration with Related Institute



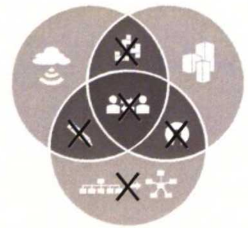
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Film and Television BA+MA

Implementing teaching: Each time the students work together in a group (as in the Cinematography I Course, where directing, writing and cinematography students work together with theatre students) there is an important value-added element.

114. Open to Collaborate

Connection to Related Schools



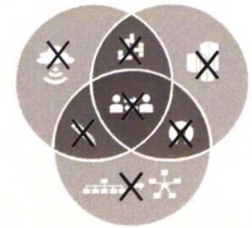
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Art & Design, Film and Television BA+MA

Evaluation and Development: The connection with other film schools is important and might be developed further (beyond Illumination or short-term visits to other schools).

115. Open to Collaborate

JOO & HEBIOT: Opportunity to Utilise Courses from Other Universities



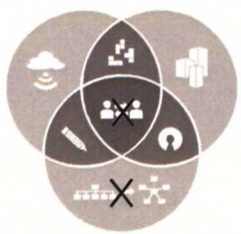
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Chemical Technology, Chemical Technology

Planning and Management: Synchronised

116. Open to Collaborate

Collaboration with another university



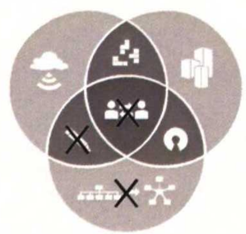
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, Economics

Planning and Management: Collaboration with the University of Helsinki

117. Open to Collaborate

New Master's degree in collaboration with another university



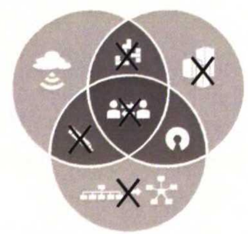
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, Economics

Planning and Management: New HECER Master's degree for ambitious students in collaboration with the University of Helsinki.

118. Open to Collaborate

Search for complementarity multidisciplinary collaboration



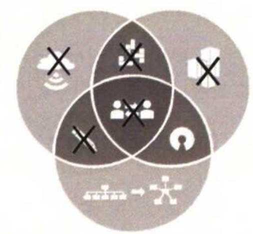
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, Finance, MSc

Planning and Management: Search for complementarity with respect to teaching, curriculum development and cross-fertilization/multi-disciplinarily

119. Open to Collaborate

Involvement of visiting lecturers and lectures from industry



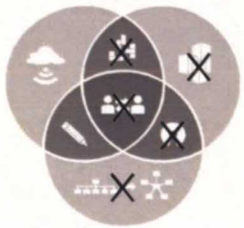
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: The School of Science, Industrial Engineering and Management and Master's Programmes in Service Management and Engineering and Strategy

Implementing teaching: Involvement of visiting lecturers and lectures from industry.

120. Open to Collaborate

Openness to serendipity allowed spontaneous collaboration with another laboratory



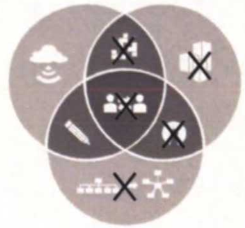
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Finance, MSc

Implementing teaching: The Department used resources for a post-doctoral position, was open to serendipity and, as a consequence, found a way to collaborate with neuroscientists (low temperature lab, Aalto School of Science's Center of Excellence)

121. Open to Collaborate

Collaboration with another university



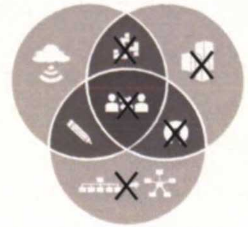
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Finance, MSc

Implementing teaching: Collaboration based on quality is established with Hanken School of Economics (Intellectual Property Rights), although such cooperation is not evident, Hanken being "a competitor just across the road"

122. Open to Collaborate

Adherence to the "open innovation" model



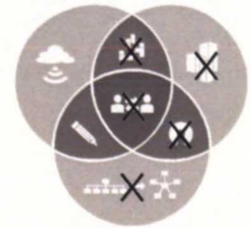
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Finance, MSc

Evaluation and Development: They clearly adhere to the "open innovation" model, advocated by Aalto

123. Open to Collaborate

Actively seek out capable teaching colleagues for core courses from outside the department, despite being such a small team



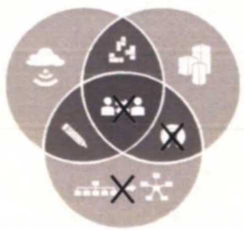
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Marketing, BSc

Implementing teaching: Actively seek out capable marketing teaching colleagues for marketing core courses not only for programmes in industrial engineering and management but also in Helsinki University and other Finnish Schools, despite being such a small team

124. Open to Collaborate

Long-term cooperation with another university



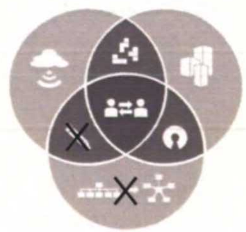
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Economics

Evaluation and Development: Long-term co-operation with the University of Helsinki

125. PBL

Customisation Based on Assignments*



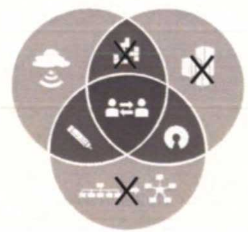
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Fine Arts

Evaluation and Development: It appears to be difficult to give courses that suit every student. There is no single course organized for all, although students are given assignments and use the general studies course to serve their needs.

126. PBL

Changing lectures into workshops where groups of students solve real industrial problems



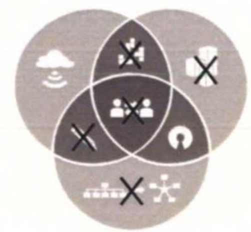
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Chemical Technology, Material Science and Engineering

Implementing teaching: The course MT-0.1007 "Basics of chemical thermodynamics" has changed four lectures to workshops. In the workshops student groups of four solve real industrial thermodynamic problems. The professor and the assistant are present in the workshops as tutors and mentors. The students get feedback and a mark for the solutions handed in. These marks are added to their marks from the partial exams. The main aim was to develop skills in solving difficult problems with incomplete and/or over-defined data and to become more fluent in discussing the problems in engineering terms.

127. PBL

Field Specific Project Work



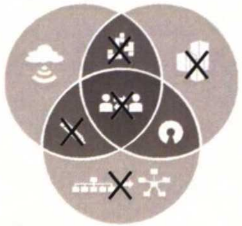
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: The School of Engineering, Mechanical Engineering

Implementing teaching: Field specific project work is an asset for the students.

128. PBL

Learning by Doing; hands-on Project Work



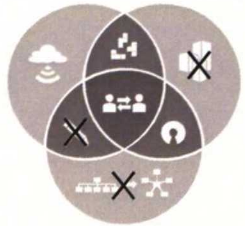
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: The School of Engineering, Architecture

Implementing teaching: learning by doing/urban space

129. PBL

Field Courses Mediate Theory and Practice



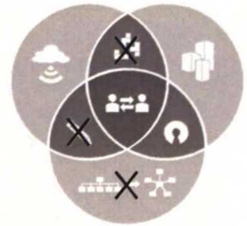
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: The School of Engineering, Landscape Architecture

Implementing teaching: Field courses excellently act as mediators between the theoretical and practical sides of the discipline and are a very good introduction to the following year's course subjects.

130. PBL

Content/Problem-oriented Perspective



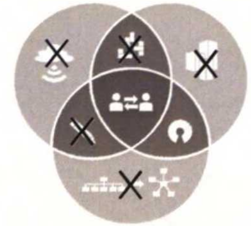
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: The School of Engineering, Master's Programme in Environmental Technology (Lahti)

Planning and Management: It takes a content/problem-oriented perspective

131. PBL

Problem-based Learning Experience in a virtual setting



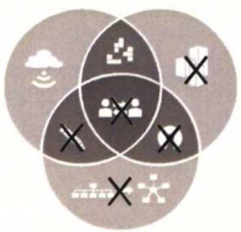
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: The School of Engineering, Master's programme in Real Estate Investment and Finance

Implementing teaching: There were problem-based learning experiences (URBAX computer game in Urban Planning and Development).

132. PBL

Joining Competitions with students from other departments



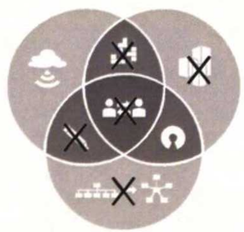
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: The School of Engineering, Structural Engineering and Building Technology

Evaluation and Development: Students together with some from Architecture compete in competitions and have been awarded prizes. This is a good practice and should be expanded.

133. PBL

Projects: Time and Freedom for Individual Study Profiles



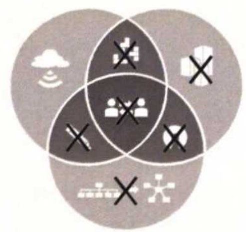
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: structure of the programme is such that the project assignments encourage time and freedom to influence individual study profiles

134. PBL

Teachers Create Joint Projects with Students and Professionals



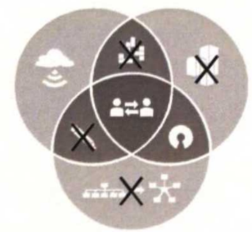
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: School of Art & Design, Creative Business Management and Visual Culture MA

Planning and Management: The teachers create joint projects with students, very often collaborating with some local actors.

135. PBL

Theoretical research Must be Linked to Practice-based Assignments



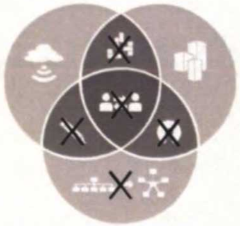
Related CDIO Standard(s): 5 Design-Implement Experience, 8 Active Learning

Discovered in: School of Art & Design, Environmental Art

Planning and Management: The students have to combine theoretical research with their practice-based assignments.

136. PBL

Learning by Doing Encourages Self-driven Progress



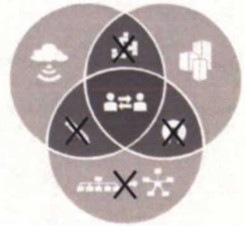
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: School of Art & Design, Environmental Art

Implementing teaching: It is up to the students to find their own way to complete their studies 'no teaching as such'. Rather, learning by doing is central

137. PBL

BA with Focus on Experimental Work



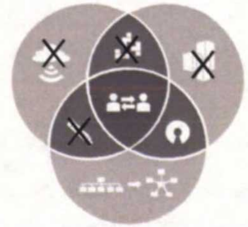
Related CDIO Standard(s): 5 Design-Implement Experience, 8 Active Learning

Discovered in: School of Art & Design, Film and Television BA+MA

Planning and Management: The new BA programme (with its focus on experimental work) is a good step in a good direction.

138. PBL

Use of databases in courses to train skills



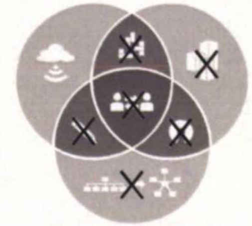
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: School of Economics, Economics

Implementing teaching: Use of databases in courses to train skills*

139. PBL

An employer-focused capstone course in conjunction with companies and other disciplines



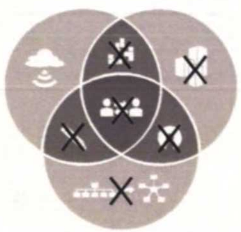
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: School of Economics, International Business, MSc (Helsinki)

Implementing teaching: The capstone course is a best practice in this programme. The capstone course in conjunction with L'Oréal has brought together IBC, IB, Marketing and Art and Design students. This course is both innovative and employer-focused

140. PBL

Co-creation of basic research agendas by incorporating real-life case studies with companies



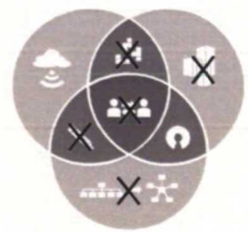
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: School of Economics, Marketing, MSc

Implementing teaching: The team successfully co-creates basic research agendas by seeking out the extensive incorporation of real-live case studies in cooperation with leading Finnish companies and multinationals. The team deserves praise for identifying, searching and thinkingof developing many novel approaches to link and connect Finnish businesses to basic field research with teaching. (We refer to the deliverables of the Advanced Consumer Behaviour course on p. 5 of the self-evaluation report, item 2d.) These kinds of creative real-life "social/business laboratory" experiments need to be encouraged and disseminated across ASE and Aalto as a best practice.

141. PBL

Wooden Town Studio



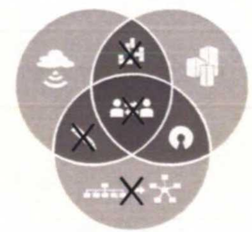
Related CDIO Standard(s): 6 Engineering Workspaces,

Discovered in: The School of Engineering, Architecture

Planning and Management: the wooden town studio

142. PBL

Students Generate Examples Instead of Solving Exercises



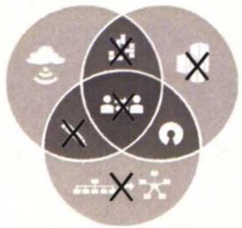
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Chemical Technology, Chemical Technology

Implementing teaching: in general chemistry courses learning outcomes were improved when exercises were modified so that instead of copying the right answers, students thought over the examples by themselves under the instruction of teachers.

143. PBL

PBL Adopted Widely, Even as Part of a Lecture-based Course



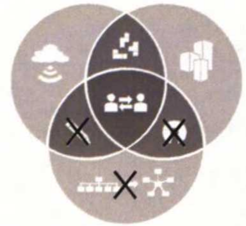
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Chemical Technology, Chemical Technology

Evaluation and Development: Problem-based learning (PBL) was established as a teaching method to support the students' thinking and problem-solving skills as well self-oriented learning. The use of the PBL method was started in the laboratory course of industrial chemistry in 2004.Later on, after successful results in learning outcomes and positive feedback from students, it was also introduced in the Bachelor's level laboratory course in the Process and products major. Recently PBL has also been implemented in a lecture-based course, in order to offer project work in groups as an alternative method for studying in addition to a traditional exam.

144. Pedagogical Awareness

Pedagogical Training for Staff



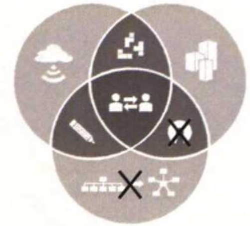
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: The School of Engineering, Geomatics

Implementing teaching: Most of the staff completed pedagogical studies for university teachers

145. Pedagogical Awareness

Awareness of Pedagogical Competence



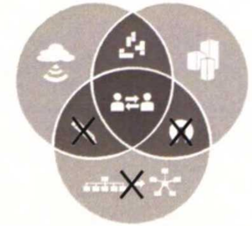
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: The School of Engineering, Master's Programme in Environmental Technology (Lahti)

Evaluation and Development: There is an awareness of pedagogical competences.

146. Pedagogical Awareness

Attitude: "Art can be Taught"



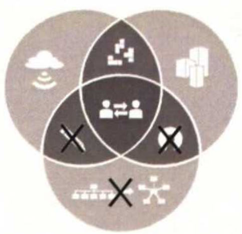
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Evaluation and Development: "It is possible to teach art" – this is a very strong and positive statement.

147. Pedagogical Awareness

Pedagogical Training for MA Students



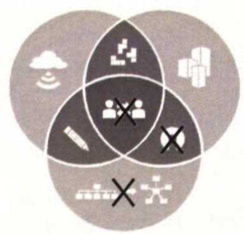
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Art & Design, Fine Arts

Implementing teaching: Courses are also given for art education at the MA level, so the pedagogically oriented students can benefit from this art education.

148. Pedagogical Awareness

Culture of Peer Review for Teachers



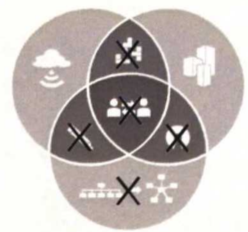
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Evaluation and Development: There is a culture of peer review; improvement is based on peer reviewing of teaching among teachers.

149. Pedagogical Awareness

Using Research Findings to Adopting Teaching Practices



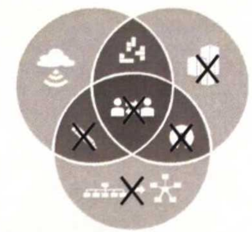
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Chemical Technology, Chemical Technology

Evaluation and Development: Research findings in the field of teaching and learning have enhanced the use of versatile teaching methods like PBL, group work, weekly assignments and learning diaries to activate students in constant studying and learning. The use of various learning and teaching methods should be supported by the Schools and the University.

150. Pedagogical Awareness

Staff Participates in Engineering Education Research and Conferences



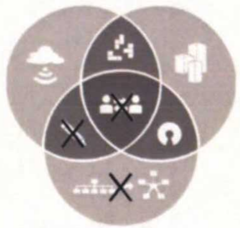
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Chemical Technology, Chemical Technology

Evaluation and Development: The participation of staff members in engineering education research and in pedagogical conferences and who present research results enhances the development of teaching and learning methods. This is an example of best practice that could be extended in the programme, the School and the University for the benefit of the whole academic community.

151. Pedagogical Awareness

Joining international teacher's programmes, and using study diaries*



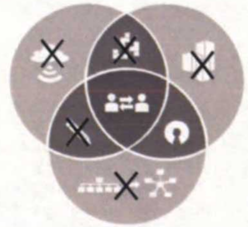
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Economics, School of Economics, Accounting, MSc

Implementing teaching: individual pioneering in joining the international teachers' programme and starting learning diaries in, for example, capital budgeting and corporate governance courses. The Accounting Department should implement this throughout the Department and implement more systematic, continuous, professional development.

152. Pedagogical Awareness

Experimentation on learning pedagogies



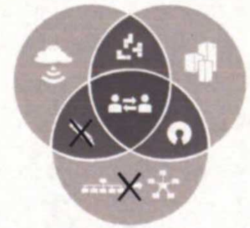
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Economics, Business Technology, BSc and Information and Service Management, MSc

Implementing teaching: Experimentation on learning pedagogies.

153. Pedagogical Awareness

PhD students who contribute to teaching are required to follow a module on academic practice



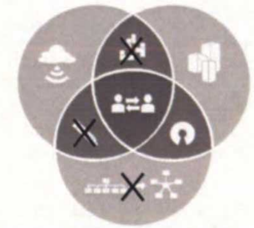
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Economics, Management

Planning and Management: PhD students who contribute to teaching are required to follow a compulsory module on academic practice that helps their initial ventures into teaching

154. Pedagogical Awareness

programme management and several teachers have attended pedagogical training and display an interest in teaching



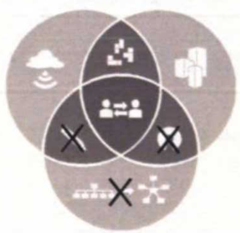
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Electrical Engineering, Communications Engineering and Master's Programme in Communications Engineering

Implementing teaching: The programme management and several teachers have attended pedagogical training and display an interest in teaching

155. Pedagogical Awareness

several academic theses written about teaching methods supporting the learning of communications engineering



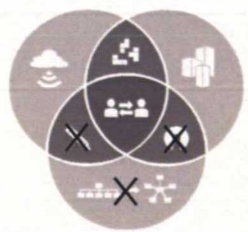
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Electrical Engineering, Communications Engineering and Master's Programme in Communications Engineering

Evaluation and Development: In recent years, several academic theses have been written about teaching methods supporting the learning of communications engineering

156. Pedagogical Awareness

The Department is currently preparing two doctoral dissertations about engineering education



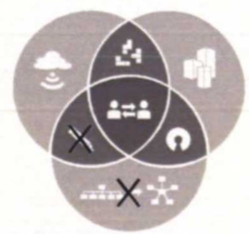
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Electrical Engineering, Electronics and Electrical Engineering and Master's Programmes in Electrical Engineering and Micro and Nanotechnology

Implementing teaching: The Department of Radio Science and Engineering is currently preparing two doctoral dissertations about electromagnetics education

157. Personal Assessment

Extra Points for Exams Can Be Gained by Doing Exercises



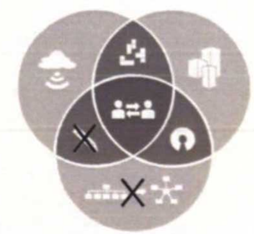
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Chemical Technology, Chemical Technology

Implementing teaching: In order to get students to work by themselves, a reward system was used by which students obtained extra points from the exercises and these points were added to the final points.

158. Personal Assessment

Self-critical Analysis



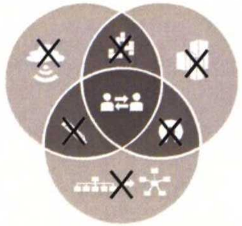
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: The School of Engineering, Architecture

Evaluation and Development: self-critical analysis

159. Personal Assessment

Informal Evaluation in a Digital Environment



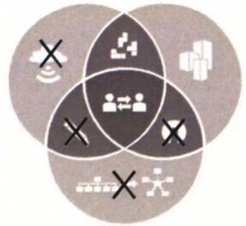
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: The School of Engineering, Geomatics

Evaluation and Development: The evaluation is mainly based on informal communications, and/or commented upon as peer-review by fellow students in the digital learning environment

160. Personal Assessment

Exemplary Oral and Written Feedback to Students



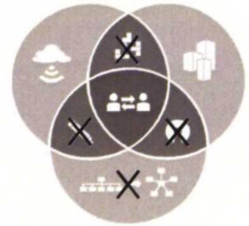
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Implementing teaching: Feedback to students both orally and written are in place. This is a good example for the BA to follow.

161. Personal Assessment

A Variety of Assessment Methods used for Learning



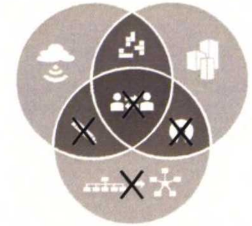
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Art Education and ePedagogy

Evaluation and Development: In both programmes feedback, assessment and evaluation are an integral part of learning and a wide variety of methods are used.

162. Personal Assessment

Collaborative Evaluation of Work and Encouragement to Discuss



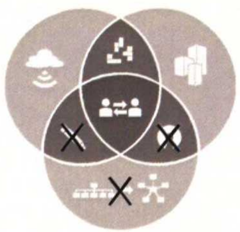
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Fine Arts

Implementing teaching: The collaborative evaluations of the artworks are central and the staff try to encourage the students to talk about their own work.

163. Personal Assessment

Personal Profiling and Many Individual Tutoring Meetings



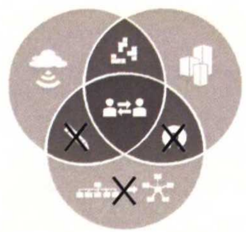
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Implementing teaching: Overall, the student profile is based on artistic quality, motivations and a wide range of skills. Tutoring is personal, with many individual meetings with the study coordinator.

164. Personal Assessment

Weekly Learning Reports for Self-Reflection



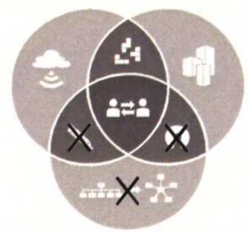
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Evaluation and Development: Students make weekly learning reports which include high levels of self-reflection.

165. Personal Assessment

Appropriate Blend of Oral and Written Self-Evaluation



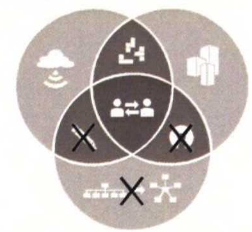
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Evaluation and Development: There was an appropriate blend of oral, written and self-evaluated feedback

166. Personal Assessment

Learning Diaries are Used for Self-reflection and Continuous Feedback



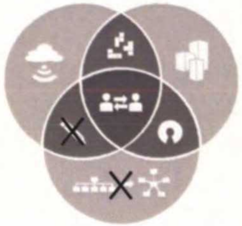
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Chemical Technology, Chemical Technology

Implementing teaching: Learning diaries are a good method for encouraging students' own thinking and analysing the subject and giving continuous feedback on learning throughout the course. The method includes the student's own work in the start-up but involves the teachers in the feedback dialogue which is positive for the students.

167. Personal Assessment

Milestone self evaluation activities in courses



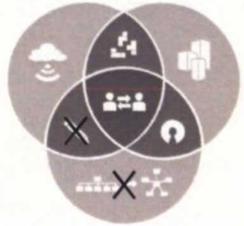
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Chemical Technology, Material Science and Engineering

Planning and Management: "The students are asked twice during the course to make a self-evaluation of how they have achieved these goals." The idea of having milestone activities in the course/project is a fine way to guide the students towards obtaining their goals.

168. Personal Assessment

Learning diaries and feedback for them



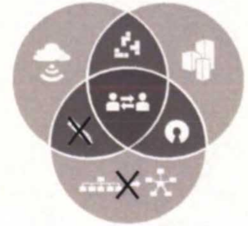
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Economics, Accounting, Finance and Business Law, BSc

Implementing teaching: There are learning diaries and quick feedback on the students' learning notebooks in two courses.

169. Personal Assessment

Good examples and self-reflection



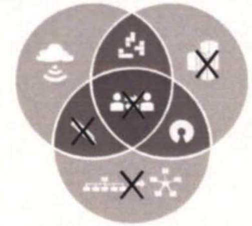
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Economics, Business Technology, BSc and Information and Service Management, MSc

Planning and Management: Good examples and self-reflection.

170. Personal Assessment

collaborative work and summatively assessed group work that rewarded individual contributions



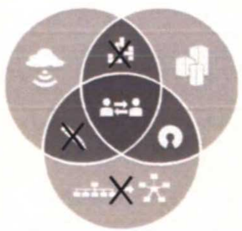
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Implementing teaching: The programme appeared to have good processes to support collaborative work and summatively assessed group work that rewarded individual contributions

171. Personalised Learning

Discussion of Individual Learning, Some Action Taken



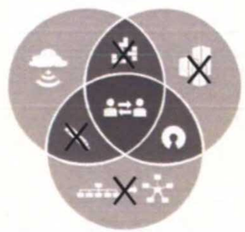
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: The School of Engineering, Transportation and Environmental Engineering

Implementing teaching: The discussion on individual learning differences and some implementations presented are interesting, and could lead to improved learning methods and results

172. Personalised Learning

Excellent student support is provided in both pastoral and academic matters



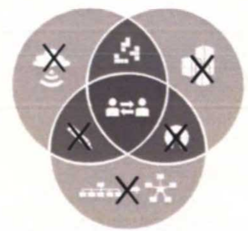
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Implementing teaching: Excellent student support is provided in both pastoral and academic matters with most students receiving appropriate support for the development of their personal study plans.

173. Personalised Learning

Personalised feedback to students wherever practical



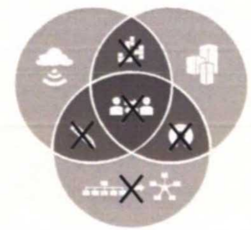
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: The School of Science, Information Networks

Implementing teaching: Personalised feedback to students wherever practical

174. Personalised Learning

Small Groups and Personal Teaching



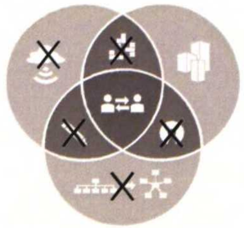
Related CDIO Standard(s): 3 Integrated Curriculum,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Implementing teaching: Small groups and personal teaching provide intensive personal development during the course modules.

175. Personalised Learning

Flexible and tolerant attitude to individual students to tailor the education to their interests



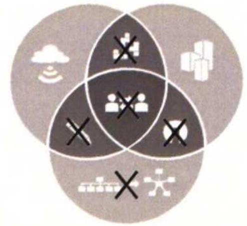
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Electrical Engineering, Electronics and Electrical Engineering and Master's Programmes in Electrical Engineering and Micro and Nanotechnology

Planning and Management: The programme displays a flexible and tolerant attitude to individual students to tailor the education to their interests

176. Positive Atmosphere

Potential for Positive Changes Within Aalto



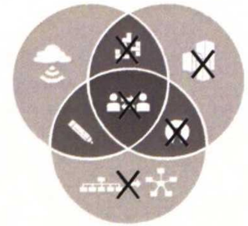
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Planning and Management: lots of potential for positive changes for the future within Aalto and in the industry/profession

177. Positive Atmosphere

Strong student satisfaction with the programme; real and vibrant spirit



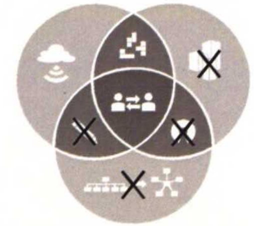
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Implementing teaching: Strong student satisfaction with the programme. The 'Mikkeli spirit' appeared both real and vibrant based on a close-knit community in which students know each other and the permanent staff.

178. Positive Atmosphere

The Programme staff is enthusiastic and committed to the student experience



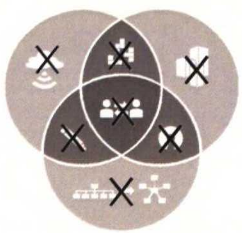
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Implementing teaching: The Programme staff were enthusiastic and committed to the student experience, enhancing the academic provision of the Mikkeli Bachelor's degree programme

179. Positive Atmosphere

Strong Student Guild support structure for students



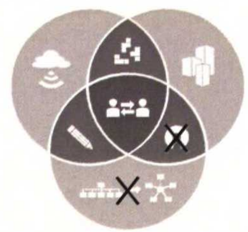
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Science, Information Networks

Implementing teaching: Strong Student Guild support structure for students

180. Positive Atmosphere

Positive Feeling from the Programme



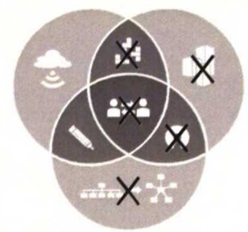
Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Engineering, Energy and HVAC-Technology

Implementing teaching: a positive basic feeling from the programme towards students and teaching

181. Positive Atmosphere

Individual support within a close-knit international community



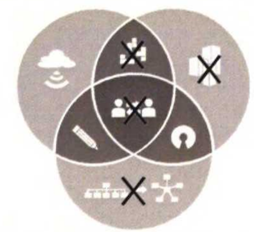
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Planning and Management: The students receive individual support within a strong, close-knit international community in which they feel they are personally known by visiting lectures and well supported.

182. Positive Atmosphere

Close-knit team with an enthusiastic approach



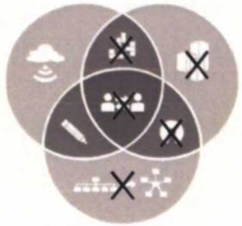
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Communication in Business and Economy, MSc and International Business Communication, MSc

Planning and Management: Close-knit team with an enthusiastic approach

183. Positive Atmosphere

Departments annual field trip where experiences and material is shared



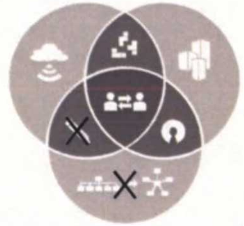
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Finance, MSc

Evaluation and Development: every three years, the whole Department goes off for the day and members of the department share experiences, and material/slides

184. Positive Atmosphere

Committed programme staff



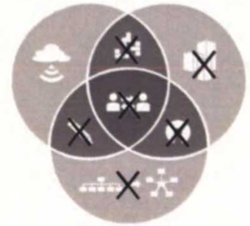
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Planning and Management: Committed programme staff

185. Positive Atmosphere

An open and friendly atmosphere, inviting creative improvements in the teaching



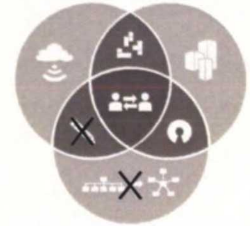
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: The School of Science, Computer Science and Engineering and Master's Programmes in Mobile Computing – Services and Security, Foundations of Advanced Computing, Machine Learning and Data Mining, Service Design and Engineering and Bioinformatics

Planning and Management: The open and friendly atmosphere, inviting creative improvements in the teaching, is an extremely valuable asset for all future work of the programme.

186. Professional Development

Many Applicants; 3% Intake



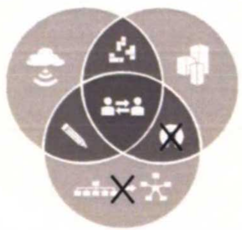
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Planning and Management: Strong intake through the selection procedure (approx. 3% intake from the applicant pool)

187. Professional Development

All Students Already Have a BA in Fine Art



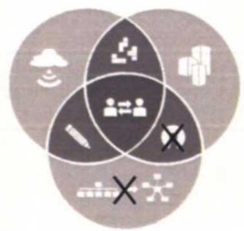
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Fine Arts

Planning and Management: All of them already have a BA in Fine Art.

188. Professional Development

Students are Fine Arts BAs or Practicing Artists



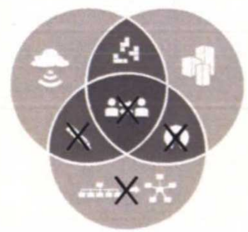
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Fine Arts

Planning and Management: The entry criterion is a BA in Fine Art. Students come directly from the BA programme or they are practising artists who feel the need to learn more and to theorize more. The two groups become merged during their studies.

189. Professional Development

Professionals Among the Teachers Working in Industry



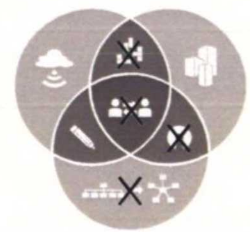
Related CDIO Standard(s): 1 The Context, 4 Introduction to Engineering

Discovered in: School of Art & Design, Film and Television BA+MA

Planning and Management: There are many artists among the teachers who are working in the industry.

190. Professional Development

Good Contact to the Field's Contemporary Professionals

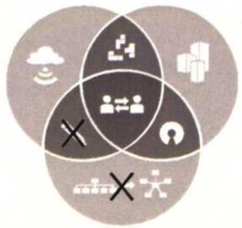


Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Design for Theatre, Film and Television BA+MA

Evaluation and Development: It is important to keep good contact with the contemporary professional field.

191. Professional Development
Students Have Prior Higher Education Experience

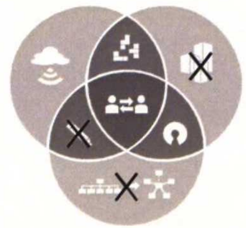


Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Planning and Management: Intake of mainly older students with prior higher education learning experience

192. Professional Development
High Level (150 Prizes Per Year by Students and Faculty)

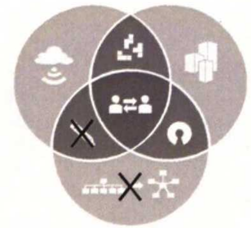


Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Planning and Management: A high level of output (150 prizes a year by both students and professors)

193. Professional Development
Professional Excellence

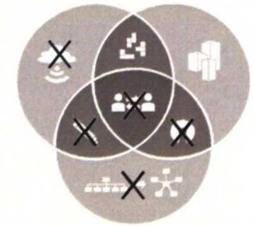


Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Architecture

Planning and Management: professional excellence in particular fields

194. Professional Development
Mapped Competences Aim for Professional Profiles

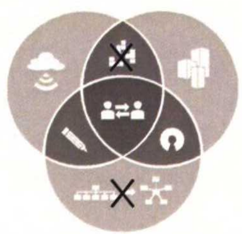


Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Energy and HVAC-Technology

Evaluation and Development: The ambitious mapping of core competences on courses that aims at professional profiles is also, from this viewpoint, an excellent effort, which will certainly also point to several desired connections outside its own domain.

195. Professional Development
Fully Employed Graduates

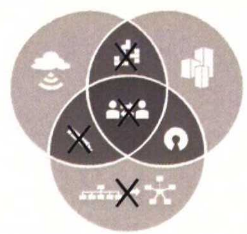


Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Geomatics

Planning and Management: Students are fully employed after graduation

196. Professional Development
Exemplary Competence and Professional Development

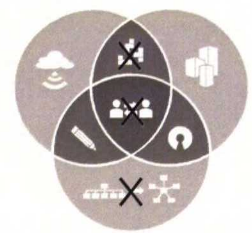


Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Landscape Architecture

Planning and Management: The Aalto Landscape Architecture programme is a model of support for the competence development and professional development of students and one that could well be emulated by other university schools and programmes.

197. Professional Development
Programme is Tailored to Market Requirements

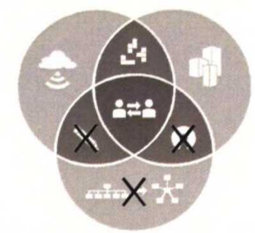


Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Real Estate Economics

Evaluation and Development: Response from industry implies that the programme is adequately tailored to market requirements

198. Professional Development
Long History of Education and Professional Continuum



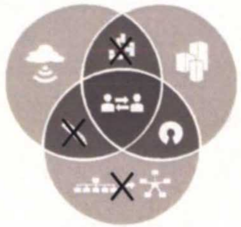
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Planning and Management: A long history of education and professional continuum

199. Professional Development

developing professional skills in graduates who are useful for companies in a wide variety of industries



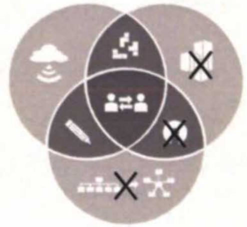
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Economics, Marketing, MSc

Planning and Management: A keen focus on developing professional skills in graduates who are useful for companies in a wide variety of industries and service sectors.

200. Professional Development

Recruitment of top students



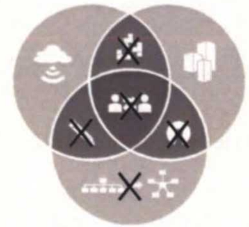
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: The School of Science, Industrial Engineering and Management and Master's Programmes in Service Management and Engineering and Strategy

Planning and Management: Recruitment of top students.

201. Programme Evaluation and Development

Teachers Reflect on Each Others Teaching Methods



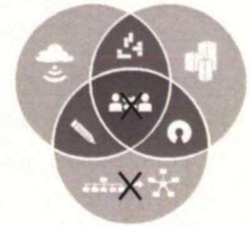
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Art & Design, Creative Business Management and Visual Culture MA

Evaluation and Development: They try to understand and reflect on what the other teachers think, and on their teaching methods. By trying to understand each other's work better they can develop their own work as well as the entire programme.

202. Programme Evaluation and Development

Identified Need for Leadership



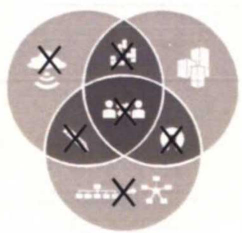
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Engineering, Energy and HVAC-Technology

Planning and Management: The degree programme has noticed the need for a leadership for the programme, and an internal 'study committee'. However, clearer authority for these needs to be developed.

203. Programme Evaluation and Development

Future Needs Analysed by a Multidisciplinary Team



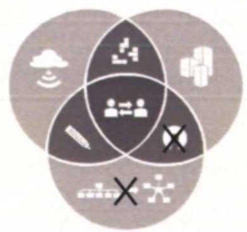
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Engineering, Geomatics

Planning and Management: A multidisciplinary team (of surveyors, cartographers, people involved in mathematics, sciences and other fields, and computer sciences) is working on the analysis of future needs

204. Programme Evaluation and Development

New Initiative for Exposing Internal Benchmarking



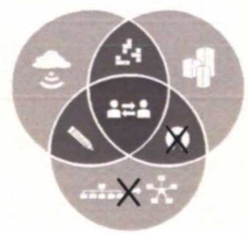
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Engineering, Master's Programme in Environmental Technology (Lahti)

Planning and Management: There is a new initiative on the internal benchmarking of the programme, and stronger binding educational formats and leaning outcomes as well as soft skills for practice.

205. Programme Evaluation and Development

Benchmarking for Course Planning



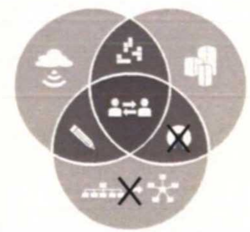
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Engineering, Master's Programme in Environmental Technology (Lahti)

Implementing teaching: Benchmarking initiative for 2012 course planning.

206. Programme Evaluation and Development

Benchmarking of Other Courses Worldwide



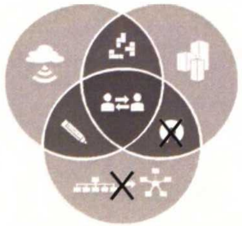
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Evaluation and Development: Applied Arts and Design is benchmarking with a lot of other courses worldwide (Staff membership on international committees, subject panels and boards etc. as well as with other Scandinavian Schools, the RCA, London, and prestigious institutions in Chinaand Japan.

207. Programme Evaluation and Development

Benchmarking of Other Modules Worldwide



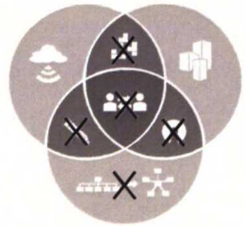
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Evaluation and Development: Industrial design benchmarks at a module level instead of the whole programme

208. Programme Evaluation and Development

Use of Gathered Information for Decision Making and Teaching



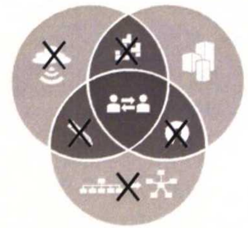
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Art Education and ePedagogy

Implementing teaching: The programme uses information to ease decision making and to familiarize new students with previous working methodologies.

209. Programme Evaluation and Development

Curriculum Planning Groups Uses Feedback and Stats for Annual Planning



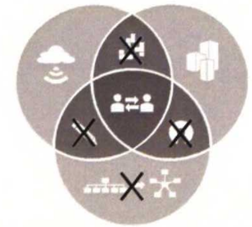
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Art Education and ePedagogy

Evaluation and Development: In Art Education a curricula planning group organises the curriculum for the academic year by reviewing the current years courses and their evaluations, study modules and course lecturing schedule. The planning group analyses the facts and statistics of each course.

210. Programme Evaluation and Development

Delaying Poorly Performing Courses, Starting Newly Proposed Courses



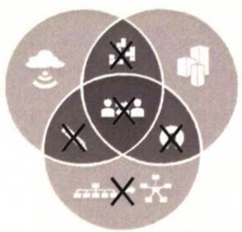
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Art Education and ePedagogy

Evaluation and Development: The group decides about delaying those courses which are not fulfilling the attendance criteria or not complying in other ways, as well as starting new courses proposed by the teachers.

211. Programme Evaluation and Development

Students' Involvement in and Programme Planning



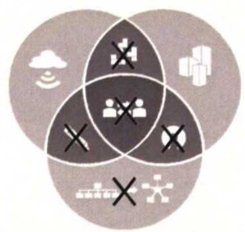
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Environmental Art

Evaluation and Development: If the students are going to give responses to the society that the professors are focused on, there should be far more student involvement in the planning of the programme.

212. Programme Evaluation and Development

New Minors and Courses Developed Between Departments and Disciplines



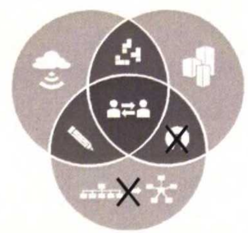
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Graphic Design BA+MA, Photography BA+MA

Evaluation and Development: New minors and courses are developed between Departments and disciplines.

213. Programme Evaluation and Development

Transparent International Benchmarking for curriculum development



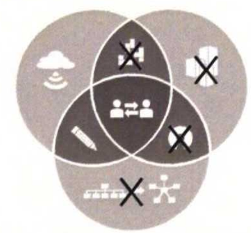
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Finance, MSc

Planning and Management: International benchmarking as a standard approach to curriculum development. (The students and graduates also recognize this)

214. Programme Evaluation and Development

dedicated 2-3 person course development task force for each course



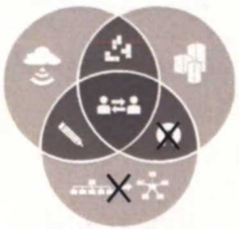
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Finance, MSc

Planning and Management: A designated course development task force for each course consisting of two or even three people (at least one professor; at least one is actually teaching the course)

215. Programme Evaluation and Development

Reflect deeply on Finnish society's view of the Bachelor's degree position in the marketplace



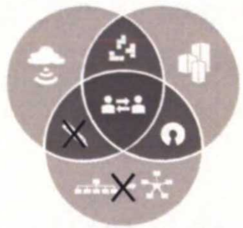
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Marketing, BSc

Planning and Management: Reflect deeply on Finnish society's view of the Bachelor's degree position in the marketplace: "Finland is not accustomed to Bachelor's degree graduates, but we think there are too many over-educated MSc students who are 28 and therefore the big Fortune 500 companies will not hire them. They will look elsewhere in Europe to staff these jobs"

216. Programme Evaluation and Development

Bringing back subjects with rediscovered importance into the core curriculum



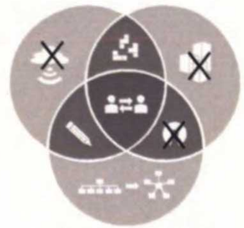
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Marketing, BSc

Implementing teaching: Bring back "sales and sales management" into the core marketing curriculum

217. Programme Evaluation and Development

Actively benchmark their programmes with leading European and US institutions



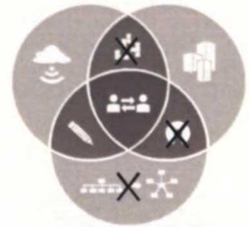
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Marketing, BSc

Evaluation and Development: Actively benchmark their programmes with leading European and US institutions

218. Programme Evaluation and Development

"fast product development": enthusiastic development and continuous renewal of the programme



Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Marketing, BSc

Evaluation and Development: Quickly, consistently, energetically, and enthusiastically develop the programme and continuously launch new editions of it. (The self-evaluation report refers to "fast product development" in various places.)

219. Programme Evaluation and Development

Experimental development; iterating, adopting, and discarding new practices

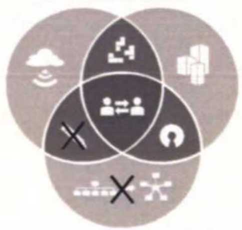
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Marketing, BSc

Evaluation and Development: Engage in experiments: try it, do it, and if it is not perfect, then fix it and keep it; or else, if it fails, have the courage to discard it without delay

220. Programme Evaluation and Development

Good ideas on how to improve a basic studies course



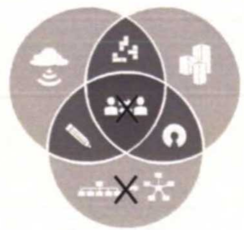
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics,

Evaluation and Development: The ideas of the marketing group on how to improve the basic studies course on "Critical Thinking and Reasoning" is certainly worth exploring

221. Programme Evaluation and Development

School Level Quality of Education Committee



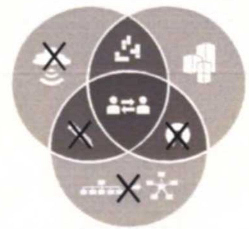
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Electrical Engineering, Bioinformation Technology

Evaluation and Development: School level: OpLaa.

222. Programme Evaluation and Development

interviews with first-year students, analysis, and suggestions for action



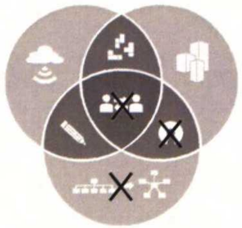
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Electrical Engineering, Communications Engineering and Master's Programme in Communications Engineering

Evaluation and Development: To analyse the low throughput at the beginning of the programme, an interview programme was carried through (interviews with first-year students, analysis, and suggestions for action)

223. Programme Evaluation and Development

Repeatedly using the Quality of Education Committee for improving courses



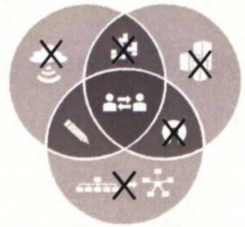
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Electrical Engineering, Electronics and Electrical Engineering and Master's Programmes in Electrical Engineering and Micro and Nanotechnology

Evaluation and Development: The programme makes repeated use of the OpLaa for improving its courses

224. Programme Evaluation and Development

Willingness to keep the content current and the programme fresh



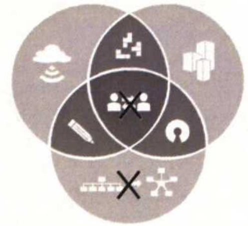
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Science, Information Networks

Evaluation and Development: Although still emerging, a clear willingness to keep the content current and the programme fresh

225. Programme Evaluation and Development

Ensuring Sufficient Staff*



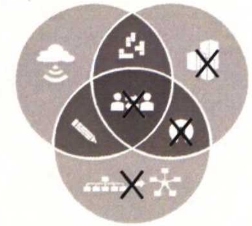
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Art & Design, Fine Arts

Evaluation and Development: There is a need to procure more staff. (There is only one professor.)

226. Programme Evaluation and Development

Biannual workshop with the teachers and employers



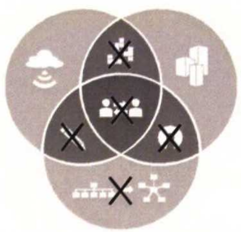
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Electrical Engineering, Bioinformation Technology

Planning and Management: The biannual workshop with the teachers and employers

227. Research in Teaching

Focus on Research/Project-based Learning



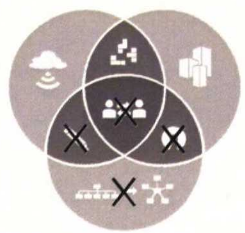
Related CDIO Standard(s): 1 The Context,

Discovered in: The School of Engineering, Geomatics

Implementing teaching: Research/project-based teaching/learning is part of the focus of the programme

228. Research in Teaching

Research is an Important Component for the Programme



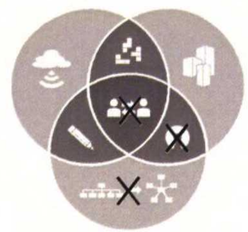
Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Implementing teaching: On-going research is an important component for the programme.

229. Research in Teaching

A research strategy (5-10 years) that is also influencing the planning of education



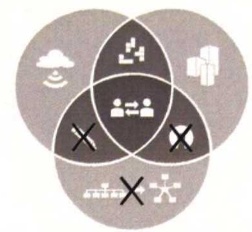
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Electrical Engineering, Communications Engineering and Master's Programme in Communications Engineering

Evaluation and Development: The Comnet Department has formulated a research strategy (5-10 years) that is also influencing the planning of education

230. Research in Teaching

Research is Directly Linked to the Teaching Process



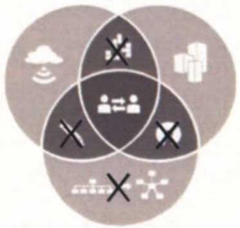
Related CDIO Standard(s): 4 Introduction to Engineering, 7 Integrated Learning Experiences

Discovered in: School of Art & Design, Film and Television BA+MA

Implementing teaching: In the field of screenwriting research is directly linked to the teaching process.

231. Research in Teaching

Applying Field-specific Research-based Problems into Basic Math Teaching



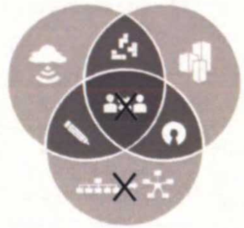
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Chemical Technology, Chemical Technology

Implementing teaching: The initiative of integrating applied chemical technology (some research-based) problems and questions into the teaching of a basic mathematics course is an excellent way of motivating students in the first study year. In this way they can immediately realize the connection and applications of basic mathematics to their future major subject.

232. Research in Teaching

The Programme has a strong research base



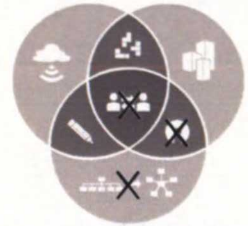
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Economics, Management

Planning and Management: The Programme has a strong research base

233. Research in Teaching

several examples of connecting teaching with research



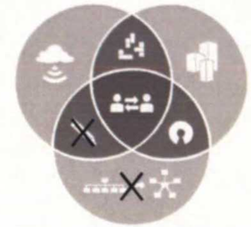
Related CDIO Standard(s): 4 Introduction to Engineering,

Discovered in: School of Electrical Engineering, Communications Engineering and Master's Programme in Communications Engineering

Implementing teaching: The programme describes several examples of connecting teaching with research, following different dimensions

234. Research in Teaching

M.Sc. theses as assignments for the research institute



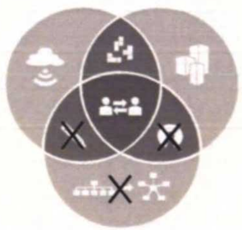
Related CDIO Standard(s): 5 Design-Implement Experience,

Discovered in: School of Economics, Economics

Evaluation and Development: M.Sc. theses as assignments for the research institute

235. Research in Teaching

Connecting Research and Teaching



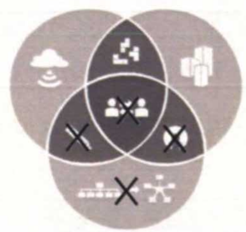
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: The School of Engineering, Real Estate Economics

Planning and Management: connection of research and teaching in innovative learning formats.

236. Research in Teaching

The results from the research are brought into practice. Clear link between the teaching and research



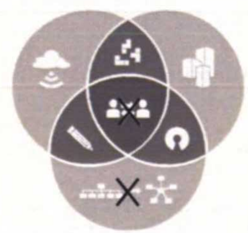
Related CDIO Standard(s): 8 Active Learning, 1 Context

Discovered in: The School of Science, Computer Science and Engineering and Master's Programmes in Mobile Computing – Services and Security, Foundations of Advanced Computing, Machine Learning and Data Mining, Service Design and Engineering and Bioinformatics

Implementing teaching: There is a clear link between the teaching and research in computer science and engineering education. The results from the research are brought into practice.

237. Research in Teaching

Coupling of research and teaching is built into the programme in the form of the special assignments



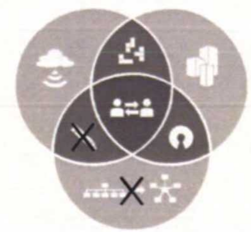
Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Science, Engineering Physics and Mathematics

Planning and Management: Excellent coupling of research and teaching is built into the programme in the form of the special assignments.

238. Scheduling Studies

three-week course structures with 45 hours of course time and compulsory attendance



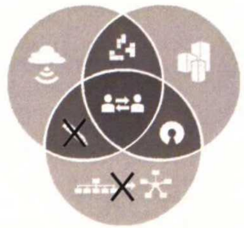
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Implementing teaching: The three-week course structures with 45 hours of course time and compulsory attendance engender good study habits in Mikkeli students.

239. Scheduling Studies

The "Bologna" emphasis on employability after the two-year and possibly accelerated one-year MSc degree



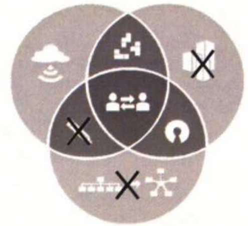
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Marketing, MSc

Planning and Management: The "Bologna" emphasis on employability after the two-year and possibly accelerated one-year MSc degree. Such an approach has merit for consideration within other Aalto Master's degree programmes, as it is line with best practices at other leading European business schools, even though traditionally Finnish society has allowed working students to stretch their Master's studies to seven or even eight years while they complete their studies.

240. Scheduling Studies

The three-zero rule in examinations is a clear rule, which stimulates more active studying in some courses



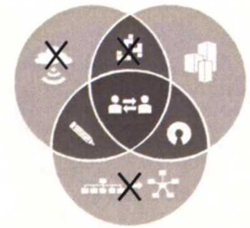
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Electrical Engineering, Electronics and Electrical Engineering and Master's Programmes in Electrical Engineering and Micro and Nanotechnology

Implementing teaching: The three-zero rule in examinations is a clear rule, which stimulates more active studying in some courses. The Department of Radio Science and Engineering is currently preparing two doctoral dissertations about electromagnetics education

241. Scheduling Studies

Regulated Schedule for Time-efficient Studies



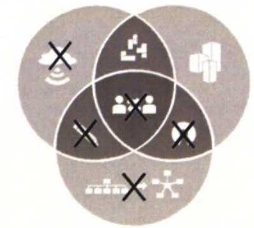
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Master's Programme in Environmental Technology (Lahti)

Planning and Management: This is a well composed and distilled core programme scheme in a regulated schedule which allows for time-efficient studies. The programme can be seen as exemplary "part-time" studies. Whether this is intended is questionable, but it opens the programme to new target groups. It also works as "full time" with the problem of the missing geographical proximity to the Helsinki and Otaniemi campuses.

242. Scheduling Studies

Creation and Constant Review of a Study Plan



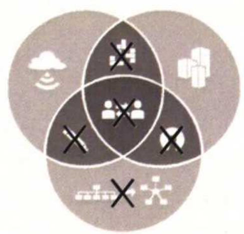
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Creative Business Management and Visual Culture MA

Implementing teaching: HOPS are created for every student during the first semester. It is renewed every year and even more often if needed. Every student has a customized study plan.

243. Scheduling Studies

Programmes Synchronise their Learning Objectives, Schedules, and Evaluation



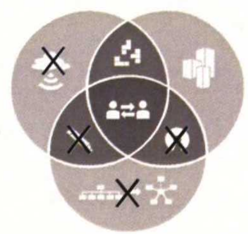
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Chemical Technology, Chemical Technology

Planning and Management: The synchronization of the courses in Biochemistry and Microbiology has been developed and implemented in terms of learning outcomes, lab organization and scheduling. The evaluation of the courses is also synchronized. This is very positive for the students in many ways; they feel that courses interact and co-operate with other courses within a programme.

244. Scheduling Studies

An idea for monitoring credit accumulation (presented in the self-evaluation report)



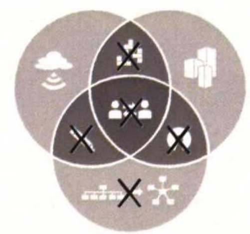
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Science, Industrial Engineering and Management and Master's Programmes in Service Management and Engineering and Strategy

Evaluation and Development: The development of an idea for monitoring credit accumulation (presented in the self-evaluation report) is excellent and should be extended at least to School level and perhaps also for the Aalto level as well.

245. Stakeholder Involvement

Directed Towards Society and Involves Stakeholders from the Society



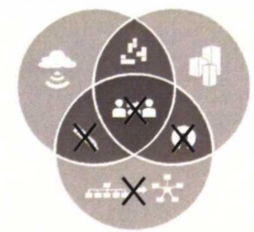
Related CDIO Standard(s): 1 The Context,

Discovered in: School of Art & Design, Environmental Art

Planning and Management: Environmental art is directed towards society; contributors from a wide range of specialists (including sociologists, political scientists and stakeholders from the community) come in to give input.

246. Stakeholder Involvement

Written Feedback from External Partners

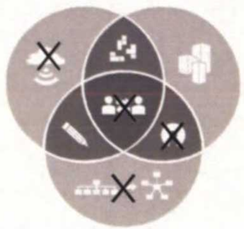


Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Environmental Art

Evaluation and Development: The external partners give written feedback

247. Stakeholder Involvement
Feedback from All Stakeholders

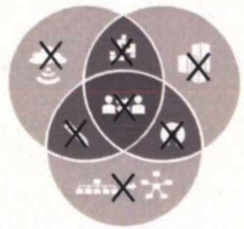


Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Engineering, Landscape Architecture

Evaluation and Development: This extends to feedback from former students, employers and other stakeholders

248. Stakeholder Involvement
Advanced Evaluation Publication by the Alumni

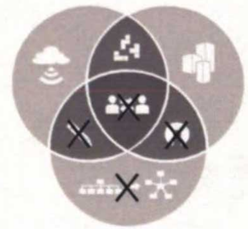


Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Engineering, Master's programme in Real Estate Investment and Finance

Evaluation and Development: There was evaluation from the ALUMNI. (An advanced publication was presented by the Head of the Degree Programme.)

249. Stakeholder Involvement
External Professionals Evaluate Thesis Work

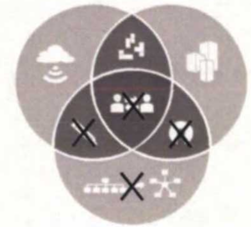


Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, Film and Television BA+MA

Evaluation and Development: Each thesis is evaluated by two evaluators, one of whom at least is a film industry professional from outside the School.

250. Stakeholder Involvement
Industrial Representatives are Involved

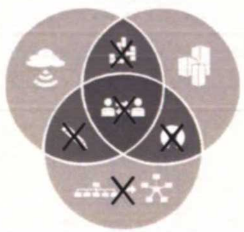


Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Planning and Management: People representing the industry are involved.

251. Stakeholder Involvement
Curriculum is Developed in Consultation with Industry

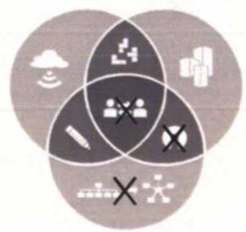


Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Art & Design, New Media MA and Sound in New Media

Evaluation and Development: The curriculum is developed in consultation with the relevant industry.

252. Stakeholder Involvement
Advisory Board Consisting of Staff and Fifteen Industrial Members



Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Chemical Technology, Chemical Technology

Evaluation and Development: The School advisory board, consisting of staff members and fifteen industrial members within relevant industrial branches, industrial associations and financial bodies, is a constructive channel with which to collect feedback from the different stakeholders and to share information. The advisory board could be a useful reference group in the future curriculum development process.

253. Stakeholder Involvement
dialogue with all stakeholders

Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Business Law, MSc

Evaluation and Development: The Business Law faculty and staff are willing to listen to and to dialogue with industry and business, alumni, students, and with faculty and researchers from other Schools both inside and outside Aalto.

254. Stakeholder Involvement
Industry and student representatives are members of the Programme Committee

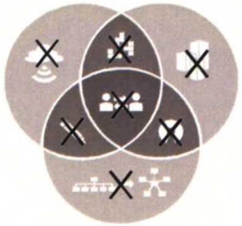
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Finance, MSc

Evaluation and Development: The faculty of the Department is willing to listen and offer dialogue: industry and student representatives are members of the Programme Committee and give appreciated advice on curriculum development

255. Stakeholder Involvement

Systematic work on improving teaching in close collaboration with students



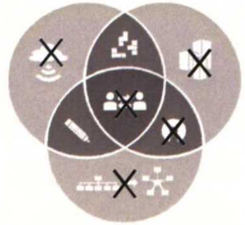
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Science, Computer Science and Engineering and Master's Programmes in Mobile Computing – Services and Security, Foundations of Advanced Computing, Machine Learning and Data Mining, Service Design and Engineering and Bioinformatics

Evaluation and Development: The programme works systematically on improving its teaching in close collaboration with the students.

256. Stakeholder Involvement

Department-level programme planning involving all the staff, and also industrial partners



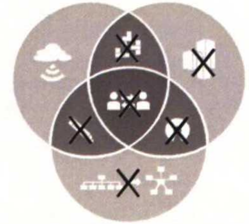
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Science, Industrial Engineering and Management and Master's Programmes in Service Management and Engineering and Strategy

Planning and Management: Department-level application of programme planning (involving all the staff in the planning, and also industrial partners).

257. Stakeholder Involvement

Fully integrating the community: planning officers, teaching staff, students, alumni, industry.



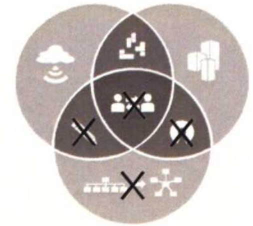
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Science, Industrial Engineering and Management and Master's Programmes in Service Management and Engineering and Strategy

Planning and Management: Fully integrating the community: planning officers, teaching staff, students, alumni, industry.

258. Stakeholder Involvement

Good Use of Stakeholder Feedback



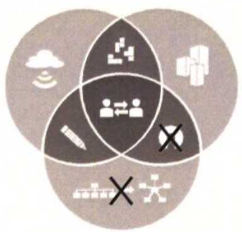
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, MA Applied Art & Design, Interior Architecture & Furniture Design, Textile Art & Design, Fashion and Clothing Design and Industrial & Strategic Design

Evaluation and Development: The Design Department demonstrated good use of stakeholder feedback such as from industry, visiting professors and alumni. These stakeholders are regularly invited to critiques and as contributors to project based assignments.

259. Stakeholder Involvement

Student representatives involved in teaching



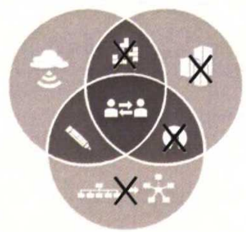
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, Business Technology, BSc and Information and Service Management, MSc

Implementing teaching: Student representatives

260. Stakeholder Involvement

use of paid student assistants develops skills, administration and the community



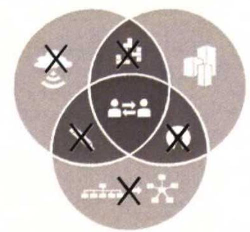
Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: School of Economics, International Business, MSc (Helsinki)

Implementing teaching: The use of paid student Voluntary Assistants is a strong feature which builds up students' skills as well as programme project administration and community development

261. Use of Virtual Tools

Competence Monitoring, Learning and Reflection with E-portfolios



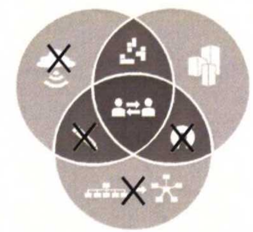
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Art & Design, Art Education and ePedagogy

Planning and Management: In the ePedagogy programme, students monitor their own competencies via e-portfolios as a tool for learning and reflection.

262. Use of Virtual Tools

defining learning outcomes coupled with state-of-the-art student assessment and feedback processes



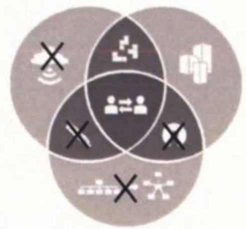
Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Economics, Marketing, MSc

Implementing teaching: There is a real understanding and focus on understanding what Bologna means by defining learning outcomes coupled with striving for pedagogical excellence in developing state-of-the-art student assessment and feedback processes. The team's skills and capabilities to give creative real-time or timely feedback using a wide variety of media (videotaping, social network media, interactive workshops and poster sessions). Also notable was the team's critical questioning of how to really measure learning outcomes, questioning and research which would be useful to share with those faculty and staff preparing AACSB and other accreditation surveys.

263. Use of Virtual Tools

Internet Survey Feedback form with both open and structured questions on each topic of the course



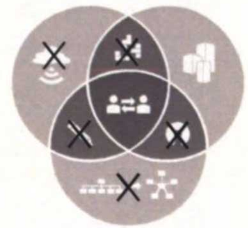
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: School of Economics, Marketing, MSc

Evaluation and Development: The programme team in the course "Quantitative Research Methods in Marketing" has invented a novel Internet Survey Feedback form with both open and structured questions on each topic of the course, which is an example of best practice. Such an Internet approach would be faster, more efficient than a paper-based system, less costly (in terms of secretarial transcribing time), and more easily shared with others.

264. Use of Virtual Tools

Utilisation of web-based systems in the development of teaching and learning



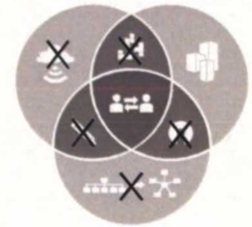
Related CDIO Standard(s): 12 Programme Evaluation,

Discovered in: The School of Science, Industrial Engineering and Management and Master's Programmes in Service Management and Engineering and Strategy

Evaluation and Development: Utilisation of web-based systems in the development of teaching and learning.

265. Use of Virtual Tools

Conception of STOPS*



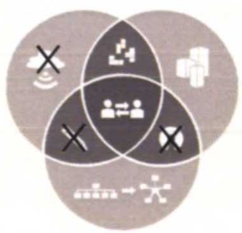
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: The School of Engineering, Structural Engineering and Building Technology

Planning and Management: The introduction of STOPS* for curriculum planning is seen as a good initiative and has the potential of great benefit for the future planning of curricula. However, one has to wait for it to be applied in practice.

266. Use of Virtual Tools

HOPS is a Good Tool when Used Properly



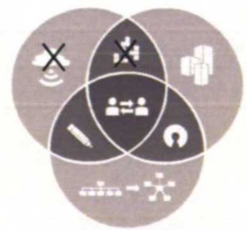
Related CDIO Standard(s): 2 Learning Outcomes,

Discovered in: School of Art & Design, Film and Television BA+MA

Planning and Management: The HOPS is a good tool when properly used.

267. Use of Virtual Tools

possibility for International work and distant participation in thesis seminars



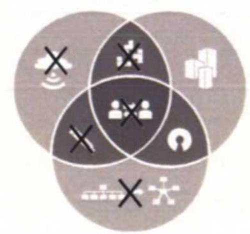
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: School of Economics, Finance, MSc

Implementing teaching: The use of video conferencing during a Master's thesis seminar by a Finnish student working for German company in Jakarta

268. Use of Virtual Tools

Use of STACK in mathematics, and real industrial and economic problems and collaboration with industry



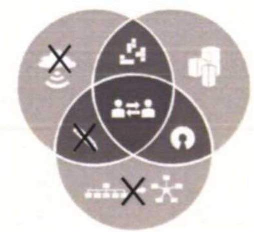
Related CDIO Standard(s): 7 Integrated Learning Experiences,

Discovered in: The School of Science, Engineering Physics and Mathematics

Implementing teaching: Use of STACK (System for Teaching and Assessment using a Computer algebra Kernel) problems in mathematics and of real industrial and economic problems and collaboration with industry (as part of the systems analysis programme).

269. Use of Virtual Tools

Virtual Tools are Integrated into Learning

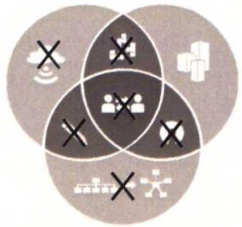


Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Engineering, Geomatics

Implementing teaching: IT infrastructure, GIS, and mobile systems are integrated into the learning process

270. Use of Virtual Tools
Use of a Virtual Laboratory in Second Life

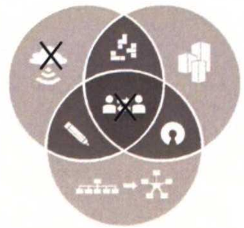


Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Chemical Technology, Chemical Technology

Implementing teaching: The virtual laboratory LabLife 3D is an innovative initiative in utilizing ICT in teaching. When it has been further developed LabLife will be useful, especially in giving students more chances to reflect on and revise the laboratory exercises without safety concerns.

271. Use of Virtual Tools
Use of the EDGE system (Electronic Decision-Making And Group work Environment)

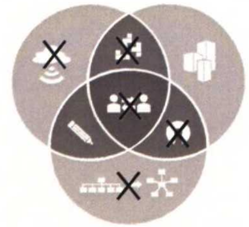


Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Economics, Business Technology, BSc and Information and Service Management, MSc

Evaluation and Development: Use of the EDGE system (Electronic Decision-Making And Group work Environment)

272. Use of Virtual Tools
TEE Collaboration Using an Open Wiki

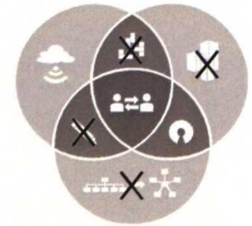


Related CDIO Standard(s): 9 Enhancement of Faculty Competence,

Discovered in: The School of Engineering, Master's programme in Real Estate Investment and Finance

Evaluation and Development: During the TEE meetings, participants used open wiki-space and worked jointly between the meetings.

273. Variety in Teaching
commitment to pedagogic research and evidence-based teaching

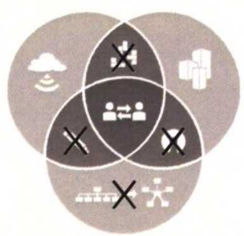


Related CDIO Standard(s): 10 Enhancement of Faculty Teaching Competence,

Discovered in: School of Economics, Management

Implementing teaching: commitment to pedagogic research and evidence-based teaching by members of the programme

274. Variety in Teaching
Assessment Focus From Exams to Course Activities

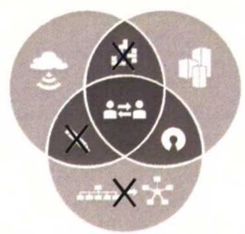


Related CDIO Standard(s): 11 Learning Assessment,

Discovered in: School of Chemical Technology, Chemical Technology

Implementing teaching: teaching methods utilising learning diaries, mind maps etc. where the focus of the assessment is transferred from the final exam towards other course activities have increased students' motivation and improved learning

275. Variety in Teaching
Implementation of Various Teaching/Learning Formats

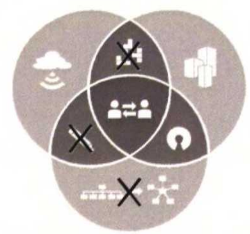


Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Engineering, Master's Programme in Environmental Technology (Lahti)

Implementing teaching: There is a variety of teaching/learning formats implemented in a holistic approach to the field of expertise.

276. Variety in Teaching
Implementation of Various Teaching/Learning Formats

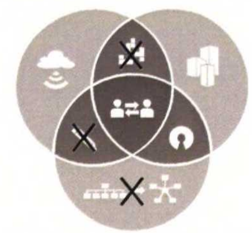


Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Engineering, Real Estate Economics

Implementing teaching: Variety of teaching/learning formats implemented

277. Variety in Teaching
Innovative Use of Teaching Methods



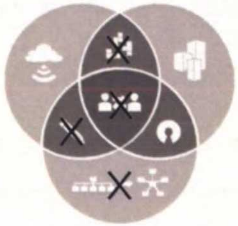
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Art & Design, Art Education and ePedagogy

Implementing teaching: In the Art Education programme the course in Environmental Education utilizes and combines different teaching methods and pedagogical solutions in a very innovative manner.

278. Variety in Teaching

Dialogical Teaching by Two Staff Members



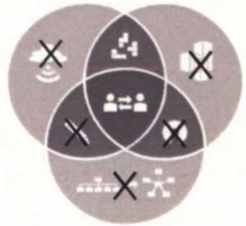
Related CDIO Standard(s): 8 Active Learning, 10 Enhancement of Faculty Teaching Competence

Discovered in: School of Art & Design, Creative Business Management and Visual Culture MA

Implementing teaching: There are courses where two staff members teach together in a form of "dialogical teaching".

279. Variety in Teaching

Innovative reflective teaching and feedback methods



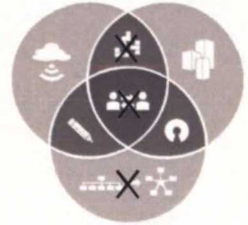
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Economics, Entrepreneurship, MSc

Implementing teaching: Innovative reflective teaching and feedback methods

280. Variety in Teaching

Fragmented programme based on three-week intensive study periods taught by visiting faculty



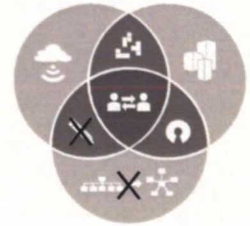
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Economics, International Business, BScBA (Mikkeli)

Implementing teaching: The Programme Director and the Manager of Academic Operations demonstrated a strong focus on enhancing quality-assurance procedures to assure student learning within a fragmented programme based on three-week intensive study periods taught by visiting faculty

281. Variety in Teaching

Special Assignments



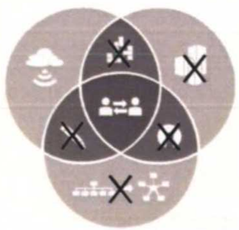
Related CDIO Standard(s): 8 Active Learning,

Discovered in: School of Electrical Engineering, Bioinformation Technology

Implementing teaching: Special Assignments.

282. Variety in Teaching

Courses are taught and assessed in a number of different ways



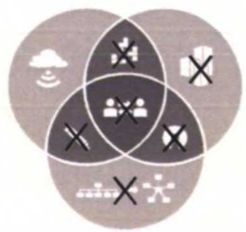
Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Science, Computer Science and Engineering and Master's Programmes in Mobile Computing – Services and Security, Foundations of Advanced Computing, Machine Learning and Data Mining, Service Design and Engineering and Bioinformatics

Implementing teaching: The courses are taught and assessed in a number of different ways. In this way, the varying learning styles within the student cohort are encouraged, at the same time as different aspects of computer science are focused on.

283. Variety in Teaching

Guidance for homework through the "Laskutupa" initiative.



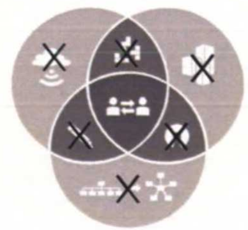
Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Science, Engineering Physics and Mathematics

Implementing teaching: Guidance for homework through the "Laskutupa" initiative.

284. Variety in Teaching

The wide variety of teaching approaches, especially the use of PBL



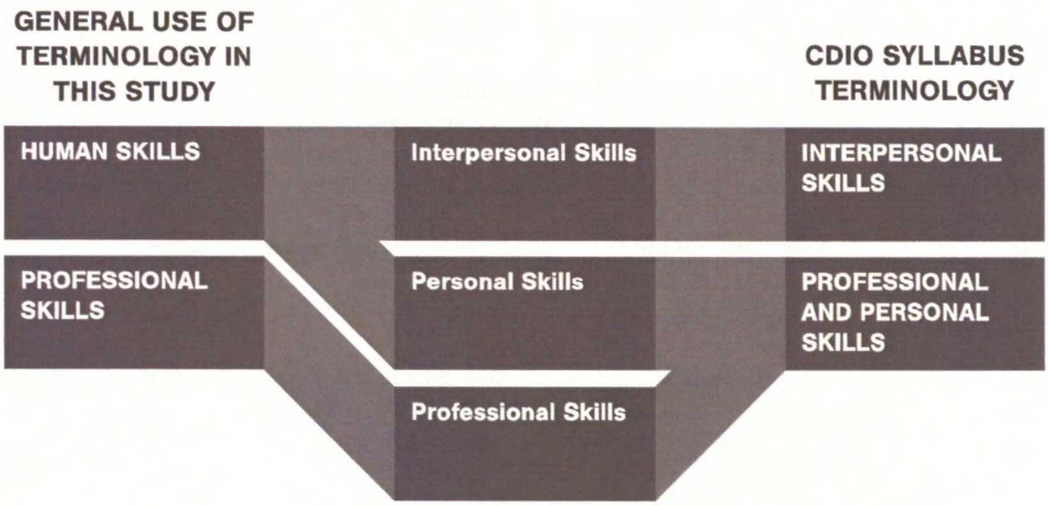
Related CDIO Standard(s): 8 Active Learning,

Discovered in: The School of Science, Information Networks

Implementing teaching: The wide variety of teaching approaches, especially the use of PBL

C. The CDIO Syllabus v2.0

Extract from Crawley, et al., 2011.



The CDIO Syllabus v2.0
June 2011

1 DISCIPLINARY KNOWLEDGE AND REASONING (UNESCO: LEARNING TO KNOW)

1.1 KNOWLEDGE OF UNDERLYING MATHEMATICS AND SCIENCES [3a]

1.1.1 Mathematics (including statistics)
1.1.2 Physics
1.1.3 Chemistry
1.1.4 Biology

1.2 CORE ENGINEERING FUNDAMENTAL KNOWLEDGE [3a]

1.3 ADVANCED ENGINEERING FUNDAMENTAL KNOWLEDGE, METHODS AND TOOLS [3k]

2 PERSONAL AND PROFESSIONAL SKILLS AND ATTRIBUTES (UNESCO: LEARNING TO BE)

2.1 ANALYTIC REASONING AND PROBLEM SOLVING [3e]

2.1.1 Problem Identification and Formulation
- Data and symptoms
- Assumptions and sources of bias
- Issue prioritization in context of overall goals
- A plan of attack (incorporating model, analytical and numerical solutions, qualitative analysis, experimentation and consideration of uncertainty)

2.1.2 Modeling
- Assumptions to simplify complex systems and environment
- Conceptual and qualitative models
- Quantitative models and simulations

2.1.3 Estimation and Qualitative Analysis
- Orders of magnitude, bounds and trends
- Tests for consistency and errors (limits, units, etc.)
- The generalization of analytical solutions

2.1.4 Analysis with Uncertainty
- Incomplete and ambiguous information
- Probabilistic and statistical models of events and sequences
- Engineering cost-benefit and risk analysis
- Decision analysis
- Margins and reserves

2.1.5 Solution and Recommendation
- Problem solutions
- Essential results of solutions and test data
- Discrepancies in results
- Summary recommendations
- Possible improvements in the problem solving process

2.2 EXPERIMENTATION, INVESTIGATION AND KNOWLEDGE DISCOVERY [3b]

2.2.1 Hypothesis Formulation
- Critical questions to be examined
- Hypotheses to be tested
- Controls and control groups

2.2.2 Survey of Print and Electronic Literature
- The literature and media research strategy

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

Information search and identification using library, on-line and database tools
Sorting and classifying the primary information
The quality and reliability of information
The essentials and innovations contained in the information
Research questions that are unanswered
Citations to references

2.2.3 *Experimental Inquiry*

The experimental concept and strategy
The precautions when humans are used in experiments
Investigations based on social science methods
Experiment construction
Test protocols and experimental procedures
Experimental measurements
Experimental data
Experimental data vs. available models

2.2.4 *Hypothesis Test and Defense*

The statistical validity of data
The limitations of data employed
Conclusions, supported by data, needs and values
Possible improvements in knowledge discovery process

2.3 SYSTEM THINKING

2.3.1 *Thinking Holistically*

A system, its function and behavior, and its elements
Transdisciplinary approaches that ensure the system is understood from all relevant perspectives
The societal, enterprise and technical context of the system
The interactions external to the system, and the behavioral impact of the system

2.3.2 *Emergence and Interactions in Systems*

The abstractions necessary to define and model the entities or elements of the system
The important relationships, interactions and interfaces among elements
The functional and behavioral properties (intended and unintended) that emerge from the system
Evolutionary adaptation over time

2.3.3 *Prioritization and Focus*

All factors relevant to the system in the whole
The driving factors from among the whole
Energy and resource allocations to resolve the driving issues

2.3.4 *Trade-offs, Judgment and Balance in Resolution*

Tensions and factors to resolve through trade-offs
Solutions that balance various factors, resolve tensions and optimize the system as a whole
Flexible vs. optimal solutions over the system lifetime
Possible improvements in the system thinking used

2.4 ATTITUDES, THOUGHT AND LEARNING

2.4.1 *Initiative and Willingness to Make Decisions in the Face of Uncertainty*

The needs and opportunities for initiative
Leadership in new endeavors, with a bias for appropriate action
Decisions, based on the information at hand
Development of a course of action
The potential benefits and risks of an action or decision

2.4.2 *Perseverance, Urgency and Will to Deliver, Resourcefulness and Flexibility*

Sense of responsibility for outcomes
Self-confidence, courage and enthusiasm
Determination to accomplish objectives

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

The importance of hard work, intensity and attention to detail
Definitive action, delivery of results and reporting on actions
Adaptation to change
Making ingenious use of the resources of the situation or group
A readiness, willingness and ability to work independently
A willingness to work with others, and to consider and embrace various viewpoints
An acceptance of feedback, criticism and willingness to reflect and respond
The balance between personal and professional life

2.4.3 *Creative Thinking*
Conceptualization and abstraction
Synthesis and generalization
The process of invention
The role of creativity in art, science, the humanities and technology

2.4.4 *Critical Thinking*
Purpose and statement of the problem or issue
Assumptions
Logical arguments (and fallacies) and solutions
Supporting evidence, facts and information
Points of view and theories
Conclusions and implications
Reflection on the quality of the thinking

2.4.5 *Self-Awareness, Metacognition and Knowledge Integration*
One's skills, interests, strengths and weaknesses
The extent of one's abilities, and one's responsibility for self-improvement to overcome important weaknesses
The importance of both depth and breadth of knowledge
Identification of how effectively and in what way one is thinking
Linking knowledge together and identifying the structure of knowledge

2.4.6 *Lifelong Learning and Educating* **[3i]**
The motivation for continued self-education
The skills of self-education
One's own learning styles
Relationships with mentors
Enabling learning in others

2.4.7 *Time and Resource Management*
Task prioritization
The importance and/or urgency of tasks
Efficient execution of tasks

2.5 ETHICS, EQUITY AND OTHER RESPONSIBILITIES [3f]

2.5.1 *Ethics, Integrity and Social Responsibility*
One's ethical standards and principles
The moral courage to act on principle despite adversity
The possibility of conflict between professionally ethical imperatives
A commitment to service
Truthfulness
A commitment to help others and society more broadly

2.5.2 *Professional Behavior*
A professional bearing
Professional courtesy
International customs and norms of interpersonal contact

2.5.3 *Proactive Vision and Intention in Life*
A personal vision for one's future
Aspiration to exercise his/her potentials as a leader
One's portfolio of professional skills

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

Considering one's contributions to society
Inspiring others

2.5.4 Staying Current on the World of Engineering

The potential impact of new scientific discoveries
The social and technical impact of new technologies and innovations
A familiarity with current practices/ technology in engineering
The links between engineering theory and practice

2.5.5 Equity and Diversity

A commitment to treat others with equity
Embracing diversity in groups and workforce
Accommodating diverse backgrounds

2.5.6 Trust and Loyalty

Loyalty to one's colleagues and team
Recognizing and emphasizing the contributions of others
Working to make others successful

3 INTERPERSONAL SKILLS: TEAMWORK AND COMMUNICATION (UNESCO: LEARNING TO LIVE TOGETHER)

3.1 TEAMWORK [3d]

3.1.1 Forming Effective Teams

The stages of team formation and life cycle
Task and team processes
Team roles and responsibilities
The goals, needs and characteristics (works styles, cultural differences) of individual team members
The strengths and weaknesses of the team and its members
Ground rules on norms of team confidentiality, accountability and initiative

3.1.2 Team Operation

Goals and agenda
The planning and facilitation of effective meetings
Team ground rules
Effective communication (active listening, collaboration, providing and obtaining information)
Positive and effective feedback
The planning, scheduling and execution of a project
Solutions to problems (team creativity and decision making)
Conflict mediation, negotiation and resolution
Empowering those on the team

3.1.3 Team Growth and Evolution

Strategies for reflection, assessment and self-assessment
Skills for team maintenance and growth
Skills for individual growth within the team
Strategies for team communication and reporting

3.1.4 Team Leadership

Team goals and objectives
Team process management
Leadership and facilitation styles (directing, coaching, supporting, delegating)
Approaches to motivation (incentives, example, recognition, etc.)
Representing the team to others
Mentoring and counseling

3.1.5 Technical and Multidisciplinary Teaming

Working in different types of teams:
Cross-disciplinary teams (including non-engineer)

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

Small team vs. large team
Distance, distributed and electronic environments
Technical collaboration with team members
Working with non-technical members and teams

3.2 COMMUNICATIONS [3g]

3.2.1 *Communications Strategy*
The communication situation
Communications objectives
The needs and character of the audience
The communication context
A communications strategy
The appropriate combination of media
A communication style (proposing, reviewing, collaborating, documenting, teaching)
The content and organization

3.2.2 *Communications Structure*
Logical, persuasive arguments
The appropriate structure and relationship amongst ideas
Relevant, credible, accurate supporting evidence
Conciseness, crispness, precision and clarity of language
Rhetorical factors (e.g. audience bias)
Cross-disciplinary cross-cultural communications

3.2.3 *Written Communication*
Writing with coherence and flow
Writing with correct spelling, punctuation and grammar
Formatting the document
Technical writing
Various written styles (informal, formal memos, reports, resume, etc.)

3.2.4 *Electronic/Multimedia Communication*
Preparing electronic presentations
The norms associated with the use of e-mail, voice mail, and videoconferencing
Various electronic styles (charts, web, etc)

3.2.5 *Graphical Communications*
Sketching and drawing
Construction of tables, graphs and charts
Formal technical drawings and renderings
Use of graphical tools

3.2.6 *Oral Presentation*
Preparing presentations and supporting media with appropriate language, style, timing and flow
Appropriate nonverbal communications (gestures, eye contact, poise)
Answering questions effectively

3.2.7 *Inquiry, Listening and Dialog*
Listening carefully to others, with the intention to understand
Asking thoughtful questions of others
Processing diverse points of view
Constructive dialog
Recognizing ideas that may be better than your own

3.2.8 *Negotiation, Compromise and Conflict Resolution*
Identifying potential disagreements, tensions or conflicts
Negotiation to find acceptable solutions
Reaching agreement without compromising fundamental principles
Diffusing conflicts

3.2.9 *Advocacy*
Clearly explaining one's point of view

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

Explaining how one reached an interpretation or conclusion
Assessing how well you are understood
Adjusting approach to advocacy on audience characteristics

3.2.10 Establishing Diverse Connections and Networking
Appreciating those with different skills, cultures or experiences
Engaging and connecting with diverse individuals
Building extended social networks
Activating and using networks to achieve goals

3.3 COMMUNICATIONS IN FOREIGN LANGUAGES

3.3.1 Communications in English

3.3.2 Communications in Languages of Regional Commerce and Industry

3.3.3 Communications in Other Languages

4 CONCEIVING, DESIGNING, IMPLEMENTING AND OPERATING SYSTEMS IN THE ENTERPRISE, SOCIETAL AND ENVIRONMENTAL CONTEXT – THE INNOVATION PROCESS (UNESCO: LEARNING TO DO)

4.1 EXTERNAL, SOCIETAL AND ENVIRONMENTAL CONTEXT [3h]

4.1.1 Roles and Responsibility of Engineers
The goals and roles of the engineering profession
The responsibilities of engineers to society and a sustainable future

4.1.2 The Impact of Engineering on Society and the Environment
The impact of engineering on the environmental, social, knowledge and economic systems in modern culture

4.1.3 Society's Regulation of Engineering
The role of society and its agents to regulate engineering
The way in which legal and political systems regulate and influence engineering
How professional societies license and set standards
How intellectual property is created, utilized and defended

4.1.4 The Historical and Cultural Context
The diverse nature and history of human societies as well as their literary, philosophical and artistic traditions
The discourse and analysis appropriate to the discussion of language, thought and values

4.1.5 Contemporary Issues and Values **[3j]**
The important contemporary political, social, legal and environmental issues and values
The processes by which contemporary values are set, and one's role in these processes
The mechanisms for expansion and diffusion of knowledge

4.1.6 Developing a Global Perspective
The internationalization of human activity
The similarities and differences in the political, social, economic, business and technical norms of various cultures
International and intergovernmental agreements and alliances

4.1.7 Sustainability and the Need for Sustainable Development
Definition of sustainability
Goals and importance of sustainability
Principles of sustainability
Need to apply sustainability principles in engineering endeavors

4.2 ENTERPRISE AND BUSINESS CONTEXT

4.2.1 Appreciating Different Enterprise Cultures
The differences in process, culture, and metrics of success in various enterprise cultures: Corporate vs. academic vs. governmental vs. non-profit/NGO

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

Market vs. policy driven
Large vs. small
Centralized vs. distributed
Research and development vs. operations
Mature vs. growth phase vs. entrepreneurial
Longer vs. faster development cycles
With vs. without the participation of organized labor

4.2.2 *Enterprise Stakeholders, Strategy and Goals*
The stakeholders and beneficiaries of an enterprise (owners, employees, customers, etc.)
Obligations to stakeholders
The mission, scope and goals of the enterprise
Enterprise strategy and resource allocation
An enterprise's core competence and markets
Key alliances and supplier relations

4.2.3 *Technical Entrepreneurship*
Entrepreneurial opportunities that can be addressed by technology
Technologies that can create new products and systems
Entrepreneurial finance and organization

4.2.4 *Working in Organizations*
The function of management
Various roles and responsibilities in an organization
The roles of functional and program organizations
Working effectively within hierarchy and organizations
Change, dynamics and evolution in organizations

4.2.5 *Working in International Organizations*
Culture and tradition of enterprise as a reflection of national culture
Equivalence of qualifications and degrees
Governmental regulation of international work

4.2.6 *New Technology Development and Assessment*
The research and technology development process
Identifying and assessing technologies
Technology development roadmaps
Intellectual property regimes and patents

4.2.7 *Engineering Project Finance and Economics*
Financial and managerial goals and metrics
Project finance – investments, return, timing
Financial planning and control
Impact of projects on enterprise finance, income and cash

4.3 CONCEIVING, SYSTEM ENGINEERING AND MANAGEMENT [3c]

4.3.1 *Understanding Needs and Setting Goals*
Needs and opportunities
Customer needs, and those of the market
Opportunities that derive from new technology or latent needs
Environmental needs
Factors that set the context of the system goals
Enterprise goals, strategies, capabilities and alliances
Competitors and benchmarking information
Ethical, social, environmental, legal and regulatory influences
The probability of change in the factors that influence the system, its goals and resources available
System goals and requirements
The language/ format of goals and requirements
Initial target goals (based on needs, opportunities and other influences)
System performance metrics

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

Requirement completeness and consistency

4.3.2 *Defining Function, Concept and Architecture*

Necessary system functions (and behavioral specifications)

System concepts

Incorporation of the appropriate level of technology

Trade-offs among and recombination of concepts

High-level architectural form and structure

The decomposition of form into elements, assignment of function to elements, and definition of interfaces

4.3.3 *System Engineering, Modeling and Interfaces*

Appropriate models of technical performance and other attributes

Consideration of implementation and operations

Life cycle value and costs (design, implementation, operations, opportunity, etc.)

Trade-offs among various goals, function, concept and structure and iteration until convergence

Plans for interface management

4.3.4 *Development Project Management*

Project control for cost, performance and schedule

- Appropriate transition points and reviews
- Configuration management and documentation
- Performance compared to baseline

Earned value recognition

The estimation and allocation of resources

Risks and alternatives

Possible development process improvements

4.4 DESIGNING [3c]

4.4.1 *The Design Process*

Requirements for each element or component derived from system level goals and requirements

Alternatives in design

The initial design

Life cycle consideration in design

Experimental prototypes and test articles in design development

Appropriate optimization in the presence of constraints

Iteration until convergence

The final design

Accommodation of changing requirements

4.4.2 *The Design Process Phasing and Approaches*

The activities in the phases of system design (e.g. conceptual, preliminary and detailed design)

Process models appropriate for particular development projects (waterfall, spiral, concurrent, etc.)

The process for single, platform and derivative products

4.4.3 *Utilization of Knowledge in Design*

Technical and scientific knowledge

Modes of thought (problem solving, inquiry, system thinking, creative and critical thinking)

Prior work in the field, standardization and reuse of designs (including reverse engineering and refactoring, redesign)

Design knowledge capture

4.4.4 *Disciplinary Design*

Appropriate techniques, tools and processes

Design tool calibration and validation

Quantitative analysis of alternatives

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

Modeling, simulation and test
Analytical refinement of the design

4.4.5 *Multidisciplinary Design*
Interactions between disciplines
Dissimilar conventions and assumptions
Differences in the maturity of disciplinary models
Multidisciplinary design environments
Multidisciplinary design

4.4.6 *Design for Sustainability, Safety, Aesthetics, Operability and Other Objectives*
Design for:
Performance, quality, robustness, life cycle cost and value
Sustainability
Safety and security
Aesthetics
Human factors, interaction and supervision
Implementation, verification, test and environmental sustainability
Operations
Maintainability, dependability and reliability
Evolution, product improvement
Retirement, reusability and recycling

4.5 IMPLEMENTING [3c]

4.5.1 *Designing a Sustainable Implementation Process*
The goals and metrics for implementation performance, cost and quality
The implementation system design:
Task allocation and cell/unit layout
Work flow
Considerations for human user/operators
Consideration of sustainability

4.5.2 *Hardware Manufacturing Process*
The manufacturing of parts
The assembly of parts into larger constructs
Tolerances, variability, key characteristics and statistical process control

4.5.3 *Software Implementing Process*
The break down of high-level components into module designs (including algorithms and data structures)
Algorithms (data structures, control flow, data flow)
The programming language and paradigms
The low-level design (coding)
The system build

4.5.4 *Hardware Software Integration*
The integration of software in electronic hardware (size of processor, communications, etc.)
The integration of software with sensor, actuators and mechanical hardware
Hardware/software function and safety

4.5.5 *Test, Verification, Validation and Certification*
Test and analysis procedures (hardware vs. software, acceptance vs. qualification)
The verification of performance to system requirements
The validation of performance to customer needs
The certification to standards

4.5.6 *Implementation Management*
The organization and structure for implementation
Sourcing and partnering
Supply chains and logistics
Control of implementation cost, performance and schedule

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

Quality assurance
Human health and safety
Environmental security
Possible implementation process improvements

4.6 OPERATING [3c]

4.6.1 *Designing and Optimizing Sustainable and Safe Operations*
The goals and metrics for operational performance, cost and value
Sustainable operations
Safe and secure operations
Operations process architecture and development
Operations (and mission) analysis and modeling

4.6.2 *Training and Operations*
Training for professional operations:
Simulation
Instruction and programs
Procedures
Education for consumer operation
Operations processes
Operations process interactions

4.6.3 *Supporting the System Life Cycle*
Maintenance and logistics
Life cycle performance and reliability
Life cycle value and costs
Feedback to facilitate system improvement

4.6.4 *System Improvement and Evolution*
Pre-planned product improvement
Improvements based on needs observed in operation
Evolutionary system upgrades
Contingency improvements/solutions resulting from operational necessity

4.6.5 *Disposal and Life-End Issues*
The end of useful life
Disposal options
Residual value at life-end
Environmental considerations for disposal

4.6.6 *Operations Management*
The organization and structure for operations
Partnerships and alliances
Control of operations cost, performance and scheduling
Quality and safety assurance
Possible operations process improvements
Life cycle management
Human health and safety
Environmental security

The Extended CDIO Syllabus: Leadership and Entrepreneurship

This extension to the CDIO Syllabus is provided as a resource for programs that seek to respond to stakeholder expressed needs in the areas of Engineering Leadership and Entrepreneurship

4.7 LEADING ENGINEERING ENDEAVORS

Engineering Leadership builds on factors already included above, including:

- **Attitudes of Leadership – Core Personal Values and Character,** including topics in Attitudes, Thought and Learning (2.4), and in Ethics, Equity and Other Responsibilities (2.5)

See UNESCO, Four Pillars of Learning.
See ABET EC 2010, Criteria 3a – 3 k.

- **Relating to Others**, including topics in Teamwork (3.1), Communications (3.2) and potentially Communications in Foreign Languages (3.3)
- **Making Sense of Context**, including topics in External, Societal and Environmental Context (4.1), Enterprise and Business Context (4.2) Conceiving, Systems Engineering and Management (4.3) and System Thinking (2.3)

In addition there are several topics that constitute creating a **Purposeful Vision**:

4.7.1 *Identifying the Issue, Problem or Paradox (which builds on Understanding Needs and Setting Goals 4.3.1)*

Synthesizing the understanding of needs or opportunities (that technical systems can address)
Clarifying the central issues
Framing the problem to be solved
Identifying the underlying paradox to be examined

4.7.2 *Thinking Creatively and Communicating Possibilities (which builds on and expands Creative Thinking 2.4.3)*

How to create new ideas and approaches
New visions of technical systems that meet the needs of customers and society
Communicating visions for products and enterprises
Compelling visions for the future

4.7.3 *Defining the Solution (which builds on and expands Understanding Needs and Setting Goals 4.3.1)*

The vision for the engineering solution
Achievable goals for quality performance, budget and schedule
Consideration of customer and beneficiary
Consideration of technology options
Consideration of regulatory, political and competitive forces

4.7.4 *Creating New Solution Concepts (which builds on and expands 4.3.2 and 4.3.3)*

Setting requirements and specifications
The high-level concept for the solution
Architecture and interfaces
Alignment with other projects of the enterprise
Alignment with enterprise strategy, resources and infrastructure

And several topics that lead to **Delivering on the Vision:**

4.7.5 *Building and Leading an Organization and Extended Organization (which builds on 4.2.4 and 4.2.5)*

Recruiting key team members with complementary skills
Start-up of team processes, and technical interchange
Defining roles, responsibilities and incentives
Leading group decision-making
Assessing group progress and performance
Building the competence of others and succession
Partnering with external competence

4.7.6 *Planning and Managing a Project to Completion (which builds on 4.3.4)*

Plans of action and alternatives to deliver completed projects on time
Deviation from plan, and re-planning
Managing human, time, financial and technical resources to meet plan
Program risk, configuration and documentation
Program economics and the impact of decisions on them

4.7.7 *Exercising Project/Solution Judgment and Critical Reasoning (which builds on 2.3.4 and 2.4.4)*

Making complex technical decisions with uncertain and incomplete information
Questioning and critically evaluating the decisions of others
Corroborating inputs from several sources

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Evaluating evidence and identifying the validity of key assumptions
Understanding alternatives that are proposed by others
Judging the expected evolution of all solutions in the future

4.7.8 *Innovation – the Conception, Design and Introduction of New Goods and Services (which is the leadership of 4.3 and 4.4)*
Designing and introducing new goods and services to the marketplace
Designing solutions to meet customer and societal needs
Designing solutions with the appropriate balance of new and existing technology
Robust, flexible and adaptable products
Consideration of current and future competition
Validating the effectiveness of the solution

4.7.9 *Invention – the Development of New Devices, Materials or Processes that Enable New Goods and Services (which builds on 4.2.6)*
Science and technology basis and options
Imagining possibilities
Inventing a practical device or process that enables a new product or solution
Adherence to intellectual property regimes

4.7.10 *Implementation and Operation – the Creation and Operation of the Goods and Services that will Deliver Value (which are the leadership of 4.5 and 4.6)*
Leading implementing and operating
Importance of quality
Safe operations
Operations to deliver value to the customer and society

These last three items are in fact the leadership of the core processes of engineering: conceiving, designing, implementing and operating

4.8 ENGINEERING ENTREPRENEURSHIP

Engineering Entrepreneurship includes by reference all of the aspects of Societal and Enterprise Context (4.1 and 4.2), all of the skills of Conceiving, Designing, Implementing and Operating (4.3 – 4.6) and all of the elements of Engineering Leadership (4.7).

In addition, there are the entrepreneurship specific skills:

4.8.1 *Company Founding, Formulation, Leadership and Organization*
Creating the corporate entity and financial infrastructure
Team of supporting partners (bank, lawyer, accounting, etc.)
Consideration of local labor law and practices
The founding leadership team
The initial organization
The board of the company
Advisors to the company

4.8.2 *Business Plan Development*
A need in the world that you will fill
A technology that can become a product
A team that can develop the product
Plan for development
Uses of capital
Liquidity strategy

4.8.3 *Company Capitalization and Finances*
Capital needed, and timing of need (to reach next major milestone)
Investors as sources of capital
Alternative sources of capital (government, etc.)
Structure of investment (terms, price, etc.)
Financial analysis for investors
Management of finances
Expenditures against intermediate milestones of progress

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4.8.4 *Innovative Product Marketing*
Size of potential market
Competitive analyses
Penetration of market
Product positioning
Relationships with customers
Product pricing
Sales initiation
Distribution to customers

4.8.5 *Conceiving Products and Services around New Technologies*
New technologies available
Assessing the readiness of technology
Assessing the ability of your enterprise to innovate based on the technology
Assessing the product impact of the technology
Accessing the technologies though partnerships, licenses, etc.
A team to productize the technology

4.8.6 *The Innovation System, Networks, Infrastructure and Services*
Relationships for enterprise success
Mentoring of the enterprise leadership
Supporting financial services
Investor networks
Suppliers

4.8.7 *Building the Team and Initiating Engineering Processes (conceiving, designing, implementing and operating)*
Hiring the right skill mix
Technical process startup
Building an engineering culture
Establishing enterprise processes

4.8.8 *Managing Intellectual Property*
IP landscape for your product or technology
IP strategy – offensive and defensive
Filing patents and provisional patents
IP legal support
Entrepreneurial opportunities that can be addressed by technology
Technologies that can create new products and systems
Entrepreneurial finance and organization

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